

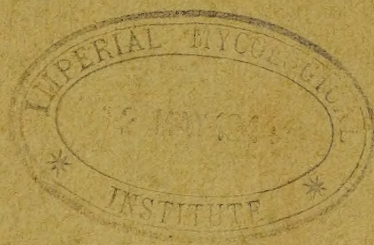
The University of Adelaide



REPORT
OF THE
WAITE AGRICULTURAL
RESEARCH INSTITUTE

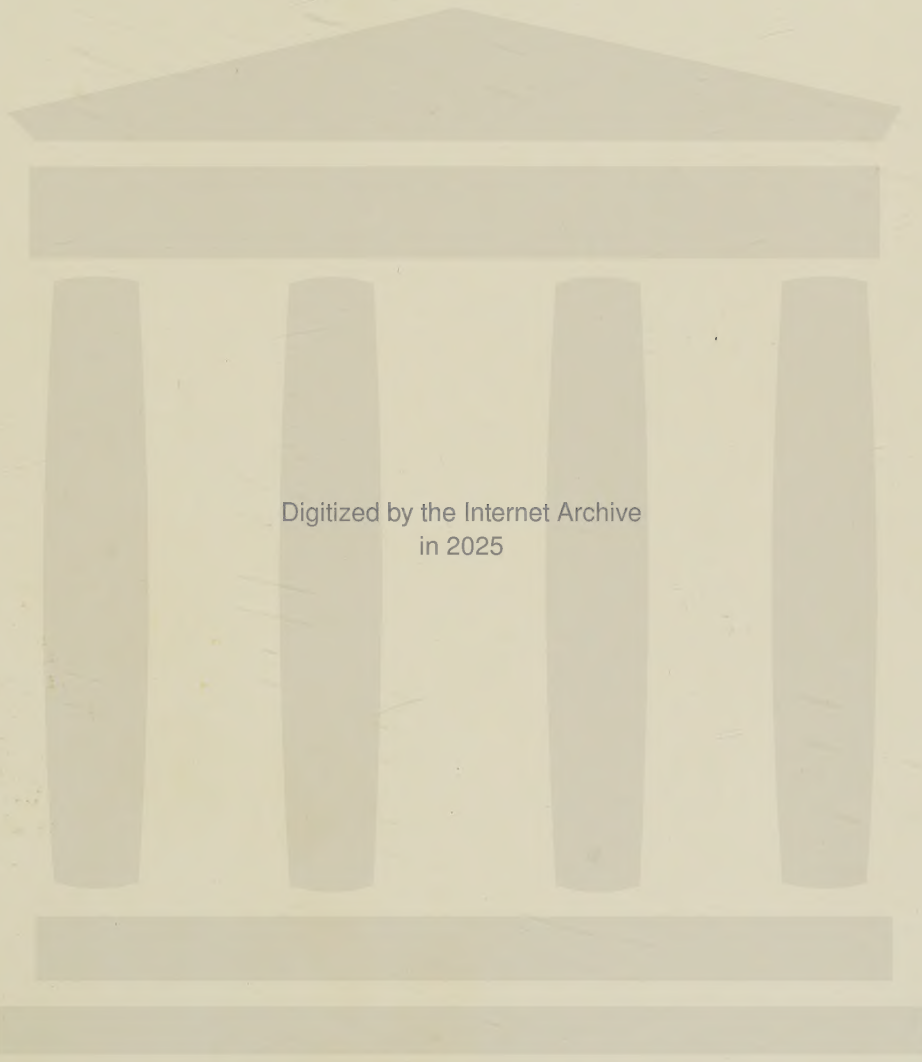
SOUTH AUSTRALIA

1941-1942

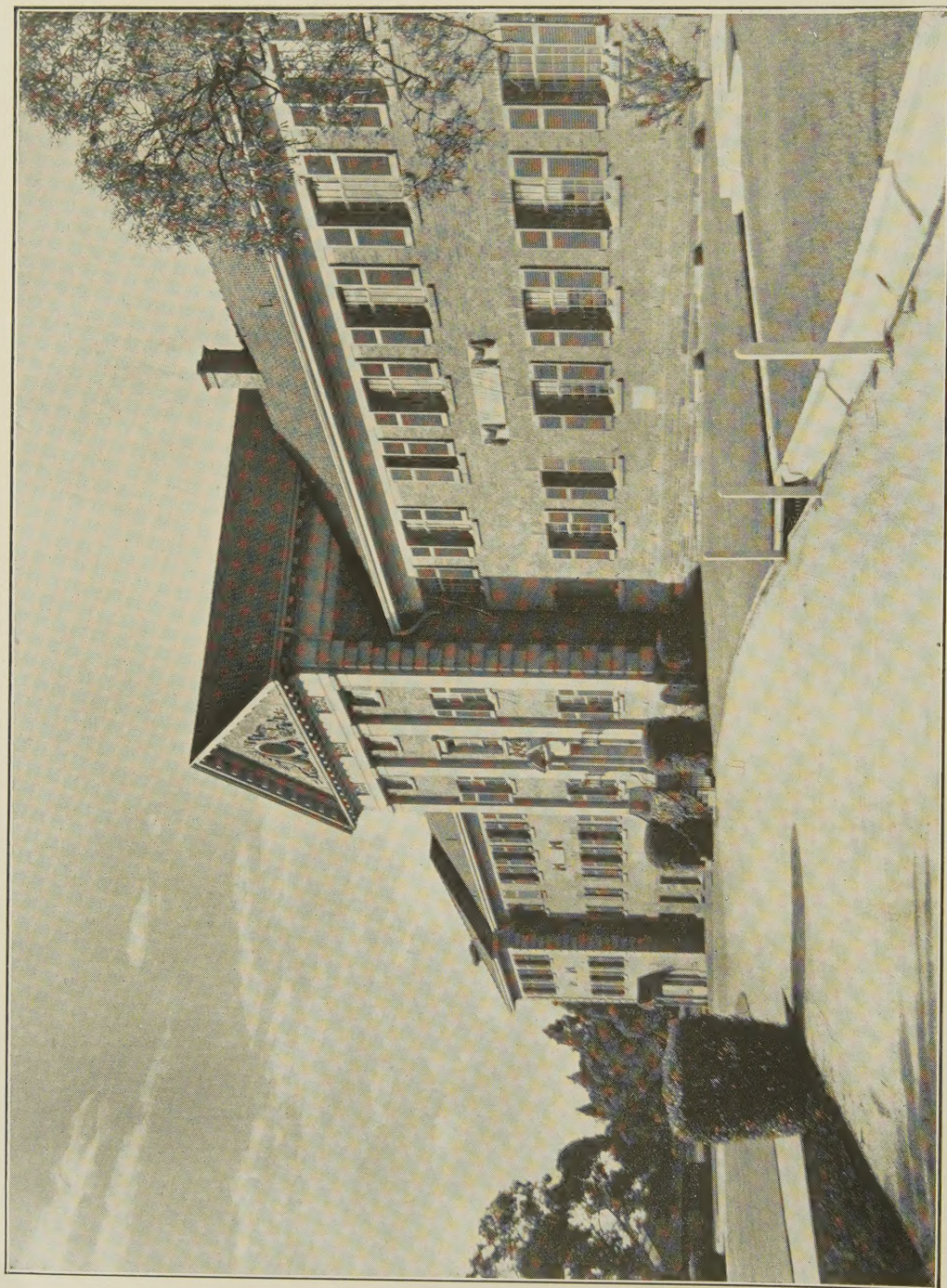


ADELAIDE
AT THE HASSELL PRESS
1943

REPORT OF
THE WAITE AGRICULTURAL
RESEARCH INSTITUTE



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THE LABORATORIES OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE

The University of Adelaide



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RESEARCH INSTITUTE

SOUTH AUSTRALIA

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Chemical Laboratory:

Chemists: R. J. BEST, M.Sc., C. S. PIPER, D.Sc., A. E. SCOTT, M.Sc.,
†*J. S. HOSKING, M.Sc., PH.D., †*A. WALKLEY, B.Sc., B.A., PH.D.
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Analytical Chemist: *R. E. SHAPTER, A.A.C.I.
Spectrographer: *A. C. OERTEL, M.Sc.
Technical Assistant: †*H. R. SKEWES.
Laboratory Assistants: †R. A. PRIEST, *C. G. GURR, †L. H. MAY, C. R. BOWES,
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Research Officers: *T. J. MARSHALL, M.A.G.Sc., PH.D., *C. G. STEPHENS, M.Sc.
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Agronomy and Agrostology:

Chief Assistant in Agronomy: †K. WOODROFFE, B.A.G.Sc.
Assistant Agrostologists: †J. R. GOODE, B.A.G.Sc., *A. J. ANDERSON, B.A.G.Sc.
Assistant Agronomists: C. A. N. SMITH, B.A.G.Sc., D. C. WARK, M.A.G.Sc.,
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Acting Geneticist: A. T. PUGSLEY, B.A.G.Sc., M.Sc.
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Wine Bacteriologist : J. C. M. FORNACHON, B.A.G.Sc.
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Laboratory Assistant : SHIRLEY E. CORRELL.

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E. A. CORNISH, *C. M. DONALD, *R. I. HERRIOT, B. W. HOLLINS, C. H. WILLIAMS.

* Officers of the Commonwealth Council for Scientific and Industrial Research.

† On service leave.

‡ Seconded to other appointments for the duration of the war.

The Waite Agricultural Research Institute

1. INTRODUCTION.

The Waite Agricultural Research Institute was established in 1924 as a result of the gift of the late Mr. Peter Waite to the University of Adelaide for the purpose of furthering the cause of education and research in agriculture and allied subjects. The original endowment comprises an estate of 299 acres of agricultural and grazing land situated near Glen Osmond, a mansion house, and a Trust Fund of £58,450.

The estate lies on the scarp of the Adelaide foothills, within four miles of the city of Adelaide. Portion of the estate comprises wheat land, 280–390 feet above sea-level, whilst the remainder is representative of the hilly country at the foothills of the Mount Lofty Ranges. To the original estate have been added 82 acres by purchase, and a further area of 115 acres associated with the Urrbrae Agricultural High School is leased from the Education Department of South Australia.

The Council of the University decided that the best means of giving effect to the wishes of the donor would be the establishment of an Agricultural Research Institute, in order to enlarge the stock of knowledge relating to agriculture in the widest sense, for the benefit of those engaged in production, as farmers or pastoralists. It appointed its Finance Committee to act as the Board of Management of the Institute.

The active work of the Institute began in March, 1925, and laboratories were improvised in the existing buildings on the estate, pending the erection of permanent structures. The permanent laboratories have been made possible through the generosity of the late Sir John Melrose, and the families of the late Mr. John Darling and Mr. Frederick Ranson Mortlock. The John Melrose Laboratory was opened in 1929, the John Darling Laboratory in 1930, and the Ranson Mortlock Laboratory in 1938.

The design of the buildings is such as to permit of additional laboratories as circumstances demand.

In addition to the laboratories, a range of glasshouses, two implement sheds, a wool shed, and a cereal barn have been erected since 1925. The glasshouses include two designed for general work in agronomy, plant pathology, and physiology, one designed for entomology, and a completely enclosed house with numerous compartments suitable for investigations demanding freedom from outside contamination, whether in the form of dust, insect pests, or bacterial infection.

This latter glasshouse has been constructed and is maintained by the Council for Scientific and Industrial Research, primarily for investigations in plant viruses and soil bacteriology.

In 1927 the Empire Marketing Board, the Council for Scientific and Industrial Research, and the University of Adelaide jointly agreed to provide funds for the investigation of the mineral content of pastures in Australia. When the Empire Marketing Board was discontinued the Trustees of the Carnegie Institution of New York provided funds over a two-year period for the maintenance of these pasture investigations, provided that the University undertook to continue the investigations subsequent to the expiry of the grant. The investigations have been continued jointly by the University and by the Council for Scientific and Industrial Research.

Since 1927 the Division of Animal Health and Nutrition of the Council for Scientific and Industrial Research has maintained at the Waite Institute a field station equipped with feeding pens and a laboratory. Here certain problems in

the nutrition of sheep, requiring relatively large numbers of animals, are investigated. Small breeding flocks of Merino and Corriedale ewes are also maintained at the Institute by the Division.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils of the Council for Scientific and Industrial Research.

Under the will of Mrs. Elizabeth Macmeikan, widow, and daughter of the late Mr. Peter Waite, who died on 5th April, 1931, her residuary estate, after payment of certain bequests, was left in trust to the University of Adelaide. The net income in the residuary estate is to be paid to the University in perpetuity for establishing and maintaining the study of agriculture, botany, zoology, veterinary science, entomology, horticulture, and forestry by the University, either in connection with the Waite Agricultural Research Institute or otherwise.

In August, 1936, the family of the late Mr. Frederick Ranson Mortlock offered the Council of the University a gift, to be known as the "Ranson Mortlock Trust", for research work in connection with soil erosion and regeneration of pastures on pastoral lands. The gift was accepted by the University, and investigations on pasture regeneration under the terms of the Trust have been initiated.

In 1941 the late Mr. Hugh Hughes, of Eureka Station in the West Darling District, bequeathed to the University half of the residue of his estate for the study of pastoral problems in Australia.

In 1941 Mr. J. T. Mortlock donated the sum of £1,000 for the erection of a residence for the overseer on the experimental area at Yudnapinna Station.

Apart from its original and subsequent endowments the Waite Research Institute derives its income from appropriations under Acts of Parliament of South Australia, from Commonwealth sources through the Council for Scientific and Industrial Research, and for specific investigations from such organizations as Imperial Chemical Industries of Australia and New Zealand, Ltd., the Australian Wool Board, and the Australian Wine Board.

Under the original deed of gift it was provided that portion of the area containing 67 acres should be held in perpetuity as a park. Effect has been given to this provision by the establishment of an arboretum in which trees can be grown to demonstrate their value for shelter and ornament, and their adaptability to the local soil and climate. More than a thousand trees in all belonging to 400 different species have been planted since 1928.

The library of the Waite Institute is designed to meet the needs of the several departments, and the policy is to make it as complete a reference library as possible on matters relating to the field of agricultural science. The present total of books is 1,800, and of bound periodicals 3,200 volumes, with an additional 30,000 unbound serials and pamphlets. The library works in close co-operation with other libraries in South Australia and in other States of the Commonwealth, and great benefit is derived from the inter-library loans that have been made possible through this co-operation.

From the beginning of 1925 until early in 1938 the Waite Institute was under the direction of Dr. A. E. V. Richardson. To Dr. Richardson and to the late Sir Walter Young (who was Chairman of the Finance Committee from 1927 to 1935) the Waite Institute is deeply indebted for the solid progress made during the early years of its establishment.

Dr. A. H. K. Petrie, head of the Department of Plant Physiology, died in his early prime in January, 1942. He had been a member of the staff since August, 1931. Acting Corporal A. J. Pike, of the farm staff, was killed in action at Tobruk in August, 1941.

In January, 1941, Mr. E. A. Cornish was appointed senior officer in charge of the Section of Biometrics of the Council for Scientific and Industrial Research,

and in March, 1941, Mr. R. I. Herriot was appointed soil conservator to the South Australian Department of Agriculture.

During the two years under review, experimental work has been conducted at country centres with the goodwill, co-operation, and personal assistance of a number of individuals and organizations. It is a pleasure to record such assistance from the following: Messrs. F. Coleman & Sons, Saddleworth; Roseworthy Agricultural College; Mr. H. Sanders, Yurgo; Mr. R. L. Davidson, Pallamana; Mr. C. J. Pitt, Ashbourne; Mr. L. B. Pfeiffer, Woodside; Mr. F. Rawnsley, Loveday; Mr. N. Brookman, Meadows; Mr. John Hawker, "Anama", Clare; Mr. J. T. Mortlock, Mr. E. E. Scarfe and Mr. D. R. Douglas, of the Yudnapinna Pastoral Company; Dr. M. Schneider and Mr. S. Schneider, Wood's Well; Mr. A. J. McBride, "Karingalana", Kangaroo Island; Mr. H. L. Rymill, "Karinga", Kangaroo Island; Mr. R. R. Wilson, Yeelanna; Mr. O. E. Halliday, Berri Experimental Orchard; Col. E. Dean and Capt. K. Rudd, Loveday Internment Camp; the late Mr. G. F. Moissey, Barmera; Mr. F. W. Harvey, Loveday; Mr. E. C. Johnson, Sherwood Irrigation Company, Loxton; Mr. G. H. McFarlane, "Brinkley", Taillem Bend; Mr. E. A. Thomas, Monarto South; Mr. C. Duval, Morphet Vale; Mr. C. Rodda, Thrington; Mr. R. Paterson, Bute; Mr. A. H. Shearer, Waitpinga; Mr. Alf. Hannaford, Waitpinga; Adelaide City Council; Mr. J. F. B. Porter, Naracoorte; Mr. N. Colley, Mount Benson; Mr. J. R. Cummings, Wattle Range; Mr. J. G. Pahl, Wattle Range; Experimental Farm, Kybybolite; Mr. S. S. Smith, Rendelsham; Mr. R. Dawson, Robe; Mr. D. V. Chapman, Houghton; Mr. A. D. Cocks, Mount Compass; Mr. F. Giles, Salisbury; Mr. A. H. Warland, Waitpinga; Kemp's Nurseries, Ltd., Kingswood; Mr. G. B. Ritchie, "Coolibah", Port Lincoln; Mr. C. S. O. Shackley, Owen; Mr. A. J. Morris, Weetulta; Mr. L. R. Watters, Curramulka; Mr. H. Cornish, Stansbury; Mr. S. C. Billinghamurst, Minnipa; Mr. E. Whitlock Jones, Cummins; Mr. C. B. Flint, Port Lincoln; Mr. A. A. Taylor, Athelstone; Messrs. R. W. Pearson and F. Chilman, Brooker; Mr. R. H. Martin, Stonyfell; Mr. F. Domaschensz, Robe; Mr. T. E. Carthew, Rendelsham.

2. SCIENTIFIC WORK OF THE INSTITUTE.

The main objective of the Institute is to enlarge the stock of knowledge relating to agriculture in the widest sense, and to pass it on to those actively engaged in agricultural and pastoral pursuits. Expressed in more precise terms, the aim is to conduct researches on plant and soil problems relating to agriculture, and on the insect and fungus pests which affect production.

Under the terms of the University of Adelaide Act 1935, and a subsequent Amendment Act of 1937, the Waite Institute, in addition to conducting researches into specified branches of agricultural science, is to provide advisory services in botany, plant pathology, and entomology to the Minister of Agriculture. By agreement these services were subsequently extended to the Minister of Afforestation.

The University of Adelaide maintains a School of Agricultural Science and courses of instruction for the degree of B.Ag.Sc. Courses of instruction in agriculture, agricultural chemistry, mycology, plant pathology, and entomology for this degree are provided at the Waite Institute. Facilities are available in the several departments of the Institute for post-graduate training and research leading to the degree of M.Sc.

Although extension work in agriculture is not a function of the Institute, educational work is effected through visits of Agricultural Bureaux, parties of farmers, and other visitors to the experimental fields and laboratories. During the period under review, the Waite Institute has co-operated with the Australian Broadcasting Commission in providing national talks from Station 5AN.

During the war an increasing number of important problems have been re-

ferred to the Institute. Of the plant problems, those relating to flax production and to the growing of the Mexican rubber plant, guayule, have been of special importance in the Agronomy Department. The necessity for storing large quantities of wheat under such conditions as to secure a minimum of loss from weevil infestation has presented a field for study by the Department of Entomology. The Soils Division has been called upon to assist in the scientific control of soil stabilization processes used in the construction of airfields.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry, and of the problems which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the research work of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy, Agrostology, and Plant Genetics.

The investigation of the factors affecting the production of farm crops; the improvement, establishment, and management of pastures; the improvement of cereals and fodder plants by hybridization and selection; the identification and control of weeds.

Plant Physiology.

The investigation of the metabolism and growth of plants of agricultural importance.

Plant Pathology.

Investigation of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

Investigation of the insect pests of agricultural and horticultural crops and of forest trees.

Agricultural Chemistry and Soil Investigations.

The survey and classification of Australian soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

Bacteriology.

The study of the nodule-forming organism of leguminous plants, with special reference to the use of strains and methods of inoculation suited to Australian crops and farming practice; investigation of problems of importance to the Australian Wine Industry.

The Work of the Institute

Agronomy, Agrostology, and Plant Genetics

The researches in progress have for their object the fuller understanding of the principles and factors affecting agricultural and pastoral practices in southern Australia. The main factors investigated are those relating to plant improvement and to climate, soil and management in their application to the increased productivity and value of farm crops and pastures.

Field experiments are being carried out to ascertain the effect of different kinds of land use on soil fertility and crop production. These have been maintained despite the impact of the war. The effect of fertilizer treatment on crops and pastures is also being investigated over a period of years. The maintenance of long-term records has enabled the significance of various climatic factors affecting agricultural production to be assessed.

The outlook in the main crop-producing areas of southern Australia has tended to change in recent years from one of cereal culture, based on wheat, bare-fallow, with some oats and barley, to one of more diversification, with an increased maintenance of livestock on cultivated land. This has led to a greater interest in rotational cropping, the growth of peas for sheep, and the establishment of temporary pastures. The possibility of developing new crops such as flax, linseed, and the rubber-bearing plants, guayule (*Parthenium argentatum*) and Russian dandelion (*Taraxacum kok-saghyz*), has also been investigated. Associated with these trends arises a need for new varieties or strains of crop and herbage plants, resistant to drought and disease, of good quality, and adapted to the environmental conditions of southern Australia.

1. FIELD CROPS.

Field investigations have been conducted since 1925 concerning the influence of different forms of crop rotation, fertilizer and cultural treatment, the variety and the time and rate of seeding on the yield of wheat. Investigations have also been carried out with oats, barley, and linseed. The main results of this work have been described in previous reports of the Waite Institute.

A permanent rotation experiment commenced in 1925 has been maintained as a project of long-term duration. Fertilizer trials on single crops were discontinued after 1937. Since the 1937 season, fertilizer effects have been investigated in association with different systems of crop rotation.

More attention has been devoted in recent years to the effects of forage and pasture plants on subsequent productivity of the soil, and to the factors affecting the production of peas, flax, and linseed.

1. PERMANENT ROTATION EXPERIMENT.

The experiment includes a comparison of eleven systems of crop rotation, commenced in 1925. In each rotation the principal crop is wheat. Each course of the eleven systems is represented in every year, so that the effects of each season upon all crops sown can ultimately be determined.

The mean yields for the first three periods of five years, 1926-30, 1931-35, 1936-40, the individual seasons 1941, 1942, and the full period of the experiment to date, 1926-42, are presented in Table 1, on page 66. The four-course rotation

has continued to produce higher yields of wheat, oats, and pasture than rotations of shorter duration.

The average yields of the main crops, for seventeen seasons, in a selected series of these rotations are shown below.

	Wheat (bush.).	Peas (bush.).	Oats (bush.).	Winter pasture (cwt. air dry).	Sudan grass (cwt. green).
Wheat continuously	15·20	—	—	—	—
Wheat, peas	27·35	20·40	—	—	—
Wheat, bare-fallow	34·53	—	—	—	—
Wheat, Sudan grass	33·72	—	—	—	25·15
Wheat, oats, fallow	35·91	—	45·53	—	—
Wheat, oats, peas	31·44	28·78	38·47	—	—
Wheat, oats, pasture, fallow	43·79	—	55·27	31·58	—

Those rotations which do not include a year of fallow have become increasingly infested with weeds.

The experiment has clearly demonstrated the value of four-course rotations, compared with those of shorter duration, in maintaining soil fertility, and it has led to the investigation of alternative four-course rotations under varying fertilizer treatment.

2. FORAGE CROPS IN RELATION TO THE GROWTH OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS.

The persistent seeding of cereals in the past has led to major losses of organic matter and of soil structure, which have caused a general decline in the fertility of the cultivated soils of southern Australia. The economic restoration of these soils depends not only on the use of longer crop rotations, but also on the choice of forage crops and/or temporary pastures that are capable of supporting maximum numbers of livestock and at the same time building organic matter and nitrogen into the soil at a sufficiently rapid rate.

In order to compare the effects of alternative forage crops on subsequent yields of temporary pasture and of wheat, an investigation was commenced in 1937 on soil that had been heavily cropped previously.

The experiment comprises five main systems of cropping, one of which is a two-course wheat bare-fallow rotation. The remaining four cropping treatments are four-course rotations, in each of which wheat sown on fallow is followed by a forage crop, viz., peas, subterranean clover, barley, or oats according to the rotation, and this is followed in turn by Wimmera rye-grass pasture.

All crops, including the pasture, received per acre a basal dressing of 2 cwt. superphosphate in 1937-41, and 1 cwt. superphosphate in 1942. Half of each plot sown to a forage crop has been harvested each year and the produce removed; the other half has been grazed *in situ*.

The yields of the forage crops on the grazed sections have been obtained from eight 5 × 5 link samples per plot, taken immediately prior to grazing. On the pastures, twelve 5 × 2½ link samples have been taken per plot prior to grazing.

The pea crop has proved the outstanding forage among those sown after wheat, averaging 49·42 cwt. of air-dry forage on the grazed sections, 43·62 cwt. total crop, and 34·01 bushels of grain on the harvested sections over the six seasons 1937-42. Subterranean clover, grown as a temporary forage, produced substantially lower yields than peas, especially in the two dry seasons, 1938 and 1940, but outyielded barley and oats over the full period (Table 2 on page 67). Peas produced higher yields than any other forage in each of the six seasons.

Marked differences in the yield of temporary pastures following the various forages have been evident throughout the period of the experiment, and these have

increased with time. In all cases greater yields were obtained after grazing than after harvesting the previous forage crop. The mean yields of pasture for six seasons were only 12.04 cwt. after oats harvested and 15.30 cwt. after oats grazed, compared with 34.00 cwt. after peas harvested and 52.34 cwt. after peas grazed. In the two most recent years, 1941 and 1942, the yields of pasture after peas grazed were 58.56 cwt. and 97.23 cwt. respectively, compared with 14.91 cwt. and 11.32 cwt. for oats harvested.

The moisture and nitrate content of the soil are being determined at the completion of the growth of the temporary pasture and at the conclusion of the period under fallow. Only slight differences in soil moisture content between the various rotational treatments have been observed. Soil nitrate has been low at the completion of the period under pasture, but has increased greatly after a period of fallow. At this stage the nitrate content to a depth of 18 inches averaged 22 parts per million after peas grazed, and 20 parts per million after peas harvested, and only 14 parts per million in the wheat-fallow rotation.

3. FERTILIZER EXPERIMENTS IN CONJUNCTION WITH DIFFERENT CROP ROTATIONS.

Four crop rotations, each based on a four-course cycle, were commenced in 1936 and 1937 on a field arrangement of 16 blocks, one block per year being devoted to a course of one rotation. All four rotations include wheat sown on fallow ploughed from temporary sown pasture. Preceding the year of pasture and following the wheat, a stubble-sown crop of peas, oats, barley, or wheat has been sown according to the rotation.

Each of the 16 blocks is made up of 27 plots, seeded or fallowed uniformly according to the rotation and its phase; and these 27 plots when sown to wheat or the succeeding crop receive 27 fertilizer combinations on a $3 \times 3 \times 3$ factorial design, covering varying levels of phosphate, nitrogen, and lime.

As there are 16 sections of 27 plots each, the experiment is made up on 432 plots. As fertilizers are applied only to the wheat and the stubble-sown crops, the yields of pasture provide a measure of the residual effects from the previous fertilizer treatments. The yields recorded in 1941 and 1942, together with the mean yields from the commencement of the experiment are shown in Table 3 on page 69.

4. FLAX INVESTIGATIONS.

Field investigations of the Liral Crown variety have been in progress since 1937, when seed imported direct from England was sown. The programme of work was designed to determine the optimum time and rate of seeding and fertilizer treatment necessary to secure maximum yields of fibre and flax seed in the Adelaide environment.

The detailed results of the trials conducted in 1941, and a summary of the yields obtained with varying time and rate of seeding, appear in Tables 4 and 5 on pages 72 and 73.

Yields of hand-pulled flax exceeding 2.5 tons per acre were recorded, with early seeding at 80 lb. seed per acre, in each of the five seasons. Yields of 3 tons per acre were obtained in both 1939 and 1940, despite exceptionally dry conditions in the latter season. In 1941 and 1942 yields of 2.88 tons and 2.81 tons respectively were recorded from seedings made in late May at 80 lb. seed per acre.

The mean yields over five seasons, with seeding rates of 40, 60, and 80 lb. per acre, were 53.67 cwt. per acre for seedings carried out in May, and 38.56 cwt. per acre for later seedings carried out in June. Late sowings thus yielded approximately 30 per cent. less flax straw than was produced from the earlier sowings.

The mean yields of flax seed for the five seasons were 10.61 bushels per acre for early sowing, and 7.95 bushels for later sowing. Seed production was more

affected by the season than was straw production. Increasing seed rates to a maximum of 80 lb. per acre tended to produce higher yields of straw and higher percentages of fibre in the straw, but a seeding rate of 40 lb. per acre produced slightly higher yields of seed than more liberal rates of seeding.

Consistently favourable reports as to the quality and percentage of fibre in the straw have been received from the Division of Forest Products, Council for Scientific and Industrial Research, which carried out retting and scutching tests on the samples from the field trials.

A total of 45 bushels of cleaned and graded Liral Crown flax seed was presented to the South Australian Flax Investigations Committee for experimental seedings in 1940, and further local seedings in 1941. The Waite Institute was strongly represented on this Committee, whose work resulted in the establishment of commercial flax growing in South Australia in 1941. The area seeded to flax in this State was 8,200 acres in 1941 and 9,818 in 1942, yielding 10,600 tons and 8,361 tons of straw respectively.

Fourteen successive harvests were made at weekly intervals between 17th September and 18th December, 1941, from flowering till several weeks after the seed had fully matured. At each of these harvests the yield of total crop, yield of seed, size of seed, and percentage viability of the seed were determined. The results are summarized in Table 6 on page 74.

The yield of straw increased up to the end of October, after which mechanical losses were evident. The yield of seed increased until mid-November. The weight per 100 seeds increased gradually until mid-November; differences thereafter were slight. Percentage viability exceeded 90 per cent. from 23rd October onwards.

The Division of Forest Products carried out determinations of the yield and quality of the fibre from samples of the plots. These provided evidence that the state of maturity affects the yield, strength, and quality of the fibre. The results of this work will be published shortly by the Council for Scientific and Industrial Research.

A dew-retting trial, conducted at the request of the Commonwealth Flax Production Committee, demonstrated that flax straw could be dew-retted satisfactorily under South Australian conditions during the winter months. The information proved valuable as a guide to the commercial retting of flax straw in South Australia. Work on the factors concerned in dew-retting was carried out in 1942.

Studies in pot cultures showed that depressed growth of the flax plant as a result of reduced water supply was due to a depression of the net assimilation rate, assessed on a protein basis. Flax was shown to possess a high stem weight ratio.

Plants grown with a liberal supply of moisture yielded a much higher percentage weight of fibre than plants subjected to partial drought after flowering. The results indicate that flax production must be limited to areas with a sufficiently long growing season, and stress the necessity for seeding early enough to ensure that growth has proceeded to a sufficient degree before the onset of dry summer conditions.

In 1942 a comparison was made of Liral Crown and Concurrent flax sown early and late. A summary of the yields is given in Table 7 on page 75. Liral Crown produced 56.30 cwt. per acre, hand-pulled, sown in May, compared with 30.94 cwt. sown in June. Concurrent produced 56.68 cwt. sown in May, and 27.11 cwt. sown in June. Yields of flax seed were the lowest for the six-year period of the trials. Seven bushels per acre were harvested from each variety sown in May; boll-worm attack was in part responsible.

Pure seed of Liral Crown flax was grown on an area of five acres to serve as stock for further multiplication under contract with the Commonwealth Flax Production Committee.

5. LINSEED.

Experimental seedings of linseed were first attempted at the Waite Institute in the three seasons 1931-33, when variable results were obtained. New Zealand and Argentine linseed yielded three to five bushels per acre when sown on fallow in May, 1931, and approximately two bushels per acre when sown in June of the same year. Calcutta linseed, sown in May, 1931 yielded 9.61 bushels per acre. In 1932, New Zealand linseed sown on fallow in early May produced 14.31 bushels per acre without fertilizer, 17.59 bushels per acre with 2 cwt. superphosphate per acre, and 23.44 bushels per acre with 2 cwt. superphosphate per acre plus 2 cwt. sulphate of ammonia per acre. In both seasons the ripening crop was attacked by Rutherglen bug (*Nysius vinitor* Berg) which caused severe damage in 1931.

Plots seeded in 1933 were dominated by hog weed (*Polygonum aviculare*), and were ploughed in for fallow when it became apparent that the linseed would be almost completely suppressed.

Work on linseed was suspended until 1940 when, because of the local shortages occasioned by the disruption of shipping between India and Australia, a further series of field experiments was commenced.

This took the form of variety trials, which included ten strains in 1940 and eleven in 1941. In each season Punjab was the outstanding variety of those tested, producing 15.75 bushels per acre in 1940 and 23.19 bushels per acre in 1941. No losses from rust attack were apparent in either season, although rust attacked linseed plots in other parts of the State. The boll-worm (*Heliothis armigera* Hb.) caused a loss of seed estimated to be 27 per cent. in 1940.

In 1942, Punjab linseed was compared with the rust resistant variety, Walsh, sown on 21st May, 8th June, 16th and 30th July. Punjab yielded 15.68 bushels per acre sown in May and 5.38 bushels per acre sown in June. Walsh yielded 4.31 bushels per acre sown in May and 2.77 bushels per acre sown in June. The July seedings were, for all practical purposes, failures. Cutworms destroyed 20-30 per cent. of seed in the Punjab variety and 50 per cent. in Walsh.

Exceptionally wet conditions were experienced following all seedings made in 1942. It was of interest that the field germination of flax was much less affected by the wet conditions than linseed. This reduction in the case of linseed was also experienced when heavy rainfall followed seeding in the seasons 1931 and 1933.

6. EVALUATION OF SEED DUSTING MATERIALS.

Further work has been carried out in the evaluation of pesticidal dusts in the control of bunt of wheat.

In 1942 a large amount of work was done to test the effects of various dusts on the germination of samples of flax seed from a number of districts, and on the germination of seed harvested at different stages of maturity at the Waite Institute.

The effect, on the germination of immature flax seed, of storage in contact with heavy dressings of these dusts for periods of up to twelve months, was also determined.

The dusts used have included either copper, organo-mercurial, or non-metallic organic compounds as their active constituents, and have been supplied by Imperial Chemical Industries of Australia and New Zealand, Ltd., who are co-operating in the work.

7. GUAYULE.

Investigations of the Mexican guayule plant (*Parthenium argentatum*) were commenced at the Waite Institute at the request of the Council for Scientific and Industrial Research in July, 1942. The work has been designed to assess the capacity of this species for the production of rubber under a wide range of conditions in southern Australia.

In view of the fact that guayule had been successfully grown for a number of years in California, it was considered that climatic conditions in South Australia would be satisfactory. Experimental plantings were made at a number of centres throughout the principal cereal-growing districts in the State, and at a number of irrigated horticultural settlements, in late winter and spring, 1942.

Most active development has occurred under irrigated conditions, and on soils of light to medium texture. In the non-irrigated areas growth has been best on medium textured soils. Heavy soils and hard-setting soils appear to be quite unsuitable.

Seed germination studies have resulted in greatly improved germination. The original seed used from plants grown at Canberra prior to 1942 was readily germinated, but this was not the case with seed received later from the U.S.A. This latter required considerable pre-treatment, and the method which has given best results to date was one developed on the basis of that previously worked out by the Intercontinental Rubber Company of America. This involves (1) mechanical washing, (2) treatment with chloride of lime, (3) centrifuging, and (4) pre-sprouting at controlled temperature and humidity.

A satisfactory nursery technique which has led to maximum field seedling establishment has been developed at Kemp's Nurseries, Ltd., and the Waite Institute. The surface covering has been found to be particularly important, and $\frac{1}{8}$ -inch fine gravel gave better results than either sand or fine charcoal. In the early stages of seedling growth it has been found necessary to keep the surface soil continuously moist. Seedlings in sufficient number to plant approximately 160 acres were raised during the 1942-43 summer.

Investigations have been pursued with all possible expedition owing to the importance of the work as a short-term war project. It has been planned to locate the bulk of the preliminary field plantings on irrigable land in an attempt to attain maximum production in a relatively short period. At the same time, the capacity of the plant under dry-land conditions is being investigated as a guide to possible post-war development.

The factors affecting growth and rubber production of the guayule plant are being investigated.

8. PEAS IN RELATION TO SOUTH AUSTRALIAN AGRICULTURE.

The importance of peas as a crop in rotation with wheat and pastures has been emphasized elsewhere in this report. The present day trend away from wheat-fallow to a wider rotation must bring with it an increase in acreage of leguminous crops such as peas, and the success which is met will depend in a large measure on the availability of suitable varieties which are adapted to the various districts of the State. With this end in view several new field peas have been introduced for inclusion in field trials in 1943. Tasmanian blue peas were grown in South Australia on a large scale (2,800 acres) for the first time in 1942. The variety is a late one, and suffered severely from attack by cutworms. A breeding programme has been commenced with a view to securing an early maturing blue pea suitable for southern Australia.

2. PLANT BREEDING AND GENETICS.

Further progress has been made in the development of new varieties of crop plants adapted to the South Australian environment. While the greater part of the work is still devoted to wheat improvement, increasing attention is now directed to the improvement of other crops such as barley, flax, linseed, peas, and potatoes. Genetic studies of disease resistance of crop plants are being continued, with

special attention to the determination of the physiological races of the various crop pathogens present in South Australia and the identification of the "disease resistant" genes as they exist in the resistant varieties available.

The most important aspect of the 1941 season was the severe and widespread epidemic of wheat stem rust (race 34. *Puccinia graminis tritici*) which caused losses in South Australia estimated at 10,000,000 bushels.

The 1942 season was an exceptionally wet and difficult one, 25 inches of rain falling during the six months May-October. Plots and rows were sown under most unfavourable conditions and the ground remained waterlogged for several weeks in early winter.

1. CEREALS.

(1) *Wheat.*

(a) *New varieties.* At the conclusion of the 1941 harvest, strain 37-76 of the crossbred Nabawa x Hope was released to farmers under the name Warigo. The variety is highly resistant to stem and leaf rusts, flag smut, loose smut, and mildew, and possesses some resistance to bunt. An account of the breeding and characteristics of Warigo has been published in the Journal of the Australian Institute of Agricultural Science, 9: 17 (1943). Because of its rust resistance, Warigo outyielded standard susceptible varieties in 1941. At the Waite Institute it yielded 38.8 bushels per acre in comparison with Ranee 16.2, while at Saddleworth the yield was 43.3 bushels per acre in comparison with Ranee 9.9.

In common with other susceptible varieties, Seewari was badly rusted in 1941, but in 1942 it yielded well in several districts of the State. It proved the most consistent variety in the 1942 trials of the Department of Agriculture, outyielding all other varieties at Yeelanna, Urania, and Georgetown.

Nabawa x Hard Federation (37-443) which has been mentioned in previous reports, continued to yield well during the seasons under review, and has been passed on for bulking prior to its release as a new variety.

(b) *Crossbred material.* Two strains of Nabawa x (Riverina x Hope) (38-356) and (39-129) were selected for country trials in 1942, and both compared more than favourably with Warigo. Both are resistant to stem and leaf rusts and flag smut. Stem rust resistant crossbreds derived from Kenya C6042 and C6040 were included in replicated trials in 1941 and 1942. The most promising of these are Kenya C6040 x Dundee (41-157), Kenya C6040 x Ranee (41-119), and Kenya C6042 x Dundee (40-109).

Rust resistant crossbreds resembling Ghurka and Ranee which have been produced by repeated back crossing of (Gluyas-Hope) to Ghurka and Ranee are now being tested in yield trials for comparison with the parent varieties. The back cross method is very well suited to the breeding of disease-resistant varieties, and its use is being extended in an endeavour to combine resistance to all the major diseases in our standard varieties. Of the susceptible material Nabawa x Hard Federation (39-453) continued to yield well. It shows distinct promise as an early maturing wheat.

(c) *Yield trials.* The cubic lattice design, introduced in 1940, has now been adopted as the standard method for testing a large number of crossbreds and varieties. In this way 125 strains are tested for yielding ability each year. A limited number of selected strains from this trial are then tested in randomized blocks at the Waite Institute and at country centres.

The results of the 1941 and 1942 yield trials at the Waite Institute, Saddleworth, and Yurgo are set out in Table on page 82 of this report. An account of the work at Saddleworth has been published in the Journal of Agriculture of South Australia 46: 354 (1943).

(d) *Disease resistance studies.* Routine tests with newly-acquired wheats from overseas have been continued. Frondosa, Frontiera, and Supreza from U.S.A. have shown a high degree of resistance to both stem and leaf rusts. They were, however, susceptible to bunt and flag smut. While Federation 38 and Baart 38, which have been reported resistant to stem rust in California, were very susceptible to this disease in 1941 and 1942, their resistance to certain races of *Tilletia levis* and *T. tritici* has been confirmed and they have also proved to be resistant to at least one race of *Ustilago tritici*. Redit, Hussar, Nebred, Oro and Rio from U.S.A., and the stem rust resistant wheats Apex, Coronation, Regent, and Renown from Canada were resistant to a collection of several races of *T. levis* and *T. tritici*. Rust-resistant spring wheats from Egypt have been tested and good agronomic types possessing additional resistance to *Urocystis tritici* have been selected for yield trials in 1943.

As a result of studies of the inheritance of resistance to *Puccinia graminis tritici* in the wheats Eureka and Warigo it has been possible to bring together in a single plant the "physiologic resistance" gene from Eureka and the "mature plant resistance" gene from Warigo. It is anticipated that this double resistance will be superior and more stable than the resistance of either Eureka or Warigo alone.

A trial to determine the reaction of Australian wheat varieties to loose smut has shown that several varieties including Bordan, Dundee, Ford, Gluyas, Gular, Rapier and Totagin are resistant to at least one race of *Ustilago tritici*.

The majority of Australian wheats are susceptible to bunt, and although seed treatment with copper carbonate gives satisfactory control at present, the production of suitable resistant varieties would overcome the necessity for seed treatment each year. A survey made in 1942 revealed the presence of *Tilletia levis* in six widely separated districts of the State. The identity of these collections is at present under investigation. Two wheats, Rio and Oro, which possess the resistant genes R and T respectively, have been selected as parents in breeding work for bunt resistance. However, as these wheats are susceptible to certain races of bunt in the United States, a search is being made for varieties possessing resistance to all races. Hope, and a durum wheat Doubbi, show promise in this direction.

A new flag smut disease of Wimmera rye-grass has been shown to be distinct from similar flag smut diseases of wheat and rye. The fungus *Urocystis* sp. is capable of infecting Wimmera rye-grass, *Lolium perenne* and *L. rigidum*, while wheat and rye remain quite free from infection.

(e) *Genetics and cytology.* Speltoid studies have been continued. Two interesting speltoid chimaeras were investigated. (1) A plant heterozygous for the tipped 1 gene ($B_1 b_1$) was found to have a single head completely bearded and speltoid. No speltoids were found in the progeny from this head, and tip-awned and bearded segregates occurred in the same proportion as those from the remainder of the plant. (2) A heterozygous speltoid plant of the Seewari variety was found to possess a single head of normal shape and with normal non-keeled glumes. The progeny from this head included speltoid and normal types in the same proportion as those from the remainder of the plant.

Cytologic and genetic evidence has been secured to support the hypothesis that *Triticum sphaerococcum* differs from *T. vulgare* in the presence of an inverted chromosomal segment.

(2) *Barley and Oats.*

Crossbred material and newly introduced varieties have been further tested for yield and resistance to disease. Crosses have been made between Rotenburger oats, which yield well on copper-deficient soils, and standard oat varieties.

Genetic studies on the inheritance of resistance to barley mildew (*Erysiphe graminis hordei*) have been commenced in an attempt to locate the six known "resistant" genes on the various chromosomes. Preliminary tests have indicated that race 3 of *Erysiphe graminis hordei* is present in South Australia.

2. FIBRE AND OIL-BEARING PLANTS.

(1) *Flax*.

Liral Crown and Concurrent are the two most widely grown varieties of fibre flax in southern Australia. Both are recent introductions from Europe, and while satisfactory results have been obtained with them at the Waite Institute and in country districts, it is felt that they will in time be replaced by improved varieties better adapted to our local conditions.

Breeding work with this crop in different parts of Australia is being co-ordinated by the Commonwealth Flax Production Committee. The first meeting of Australian flax breeders was held in Melbourne in September, 1942.

The first essential in any breeding programme is the testing and selection of newly introduced varieties. Such work with flax is now in progress, and at the same time a start has been made with the work of selection and hybridization of the more promising varieties.

Single plant and mass selections have been made from Concurrent in an attempt to isolate superior strains. Concurrent was compared with three other white-flowered varieties, and one of them—Certified White Dutch—appeared to be more uniform and superior to it.

Liral Crown, Concurrent, and the rust-resistant varieties Walsh and Ottawa 770B have been the main varieties used as parents in the breeding programme. Crosses made in the spring months have been carried through two generations (F1 and F2) during the summer and autumn months. In this way F3 material is made available for the main planting in June.

(2) *Linseed*.

Commercial Punjab and two additional strains of this variety from India have continued to give the best yields in varietal trials at the Waite Institute. Unfortunately Punjab is very susceptible to certain races of *Melampsora lini*, and it would seem that the successful establishment of linseed as a permanent crop in South Australia is dependent upon the production of suitable rust-resistant varieties. The variety Walsh, which has done well in New South Wales, has proved to be resistant to rust under South Australian conditions. This variety is being employed in conjunction with Punjab with a view to combining rust resistance with yield. Single plant selections have also been made from Punjab.

3. VEGETABLES.

(1) *Potatoes*.

Co-operative experiments with the Department of Agriculture were commenced in 1942, when yield trials were established at Ashbourne, Mount Gambier, Woodside, and Loveday. In these tests the newer American varieties Katahdin and Sebago yielded well in comparison with standard varieties such as Delaware and Carman.

Additional varieties have been secured from New South Wales and the United States. Much of this material is resistant to mild mosaic—a disease causing severe losses in the otherwise popular Carman variety.

(2) *Tomatoes.*

The task of producing new disease-resistant varieties has been carried a step further, and the resistant selections have been back crossed to the Early Dwarf Red variety.

Vetomold has proved to be resistant to the local race of *Cladosporium fulvum*, and because it has many desirable commercial qualities it is being tested alongside Early Dwarf Red in the market garden districts close to Adelaide.

Tatura Dwarf Globe—a new variety from Victoria—was included in glass-house and field trials in 1942. It showed distinct promise when compared with Early Dwarf Red.

(3) *Beans.*

Studies of the inheritance of resistance to halo blight of beans have revealed that there are at least two genes governing the resistance of bean varieties to *Phytophthora medicaginis phaseolicola*. Disease-resistant selections have been isolated from a Canadian Wonder x Burnley Selection cross.

4. PASTURE PLANTS.

(1) *Perennial Rye-grass.*

Observations were continued during 1941 and 1942 on a grazed sward trial established in 1940 of the progeny of 120 selected parent plants together with five commercial strains as controls, arranged in a cubic lattice design. The value of each strain has been judged on the basis of its relative productiveness which represents a combination of inherent vigour and the persistency of the strain.

(2) *Creeping Lucerne.*

Crosses have been made between selected creeping types and vigorous plants of the Hunter River strain. The plants from the resultant seed (F1) are grown in sand where the creeping habit can be observed in six-month-old seedlings. A study of the mode of inheritance of the creeping character requires homozygous parents, and for this purpose creeping types are being selfed through several generations.

A high percentage of plants exhibiting the creeping habit was observed in a group of 3,000 plants established from bulk seed. Observations have been continued on various strains under both single plant and sward conditions.

(3) *Subterranean Clover.*

In addition to replicated sward trials of a number of strains of subterranean clover established at the Waite Institute in 1939 and at Salisbury in 1940, further trials were commenced in 1941 at Salisbury and on the ironstone soil of the peneplain of Kangaroo Island. The Bacchus Marsh strain has proved well adapted to the soil and climatic conditions of these areas and has outyielded all other strains at each of the three centres for the duration of the experimental period. A white-seeded strain from Western Australia proved inferior to Bacchus Marsh, Mount Barker, and Dwalganup in 1941, but showed to advantage together with the Seaton Park strain under the wetter conditions prevailing in 1942.

The four commercial strains (Dwalganup, Bacchus Marsh, Mount Barker, and Tallarook) have been included in a series of pilot trials in a number of centres in order to determine the adaptability of these strains to a further range of soil and climatic conditions.

(4) *Strawberry Clover.*

Strains introduced from North America, as well as three others from Goolwa, South Australia, were tested under single plant conditions at the Waite Institute

during the 1941-42 summer against the Palestine strain as a control. None proved equal to the latter in winter production, but their summer growth has justified further trial under sward conditions.

(5) *Barrel Medic.*

Following the seed multiplication of types of barrel medic (*Medicago tribuloides*) at the Waite Institute, a sward trial embracing six strains was commenced on the calcareous coastal soil of Robe in 1941. Observations over the first two years have shown that the strain originally selected by the Waite Institute for commercial use has proved as productive as any of the other selected strains, but the trial will be continued for a further period.

3. PASTURES.

Emphasis has been given to investigations of the factors affecting pastoral production, which have formed a major part of the work in agronomy and agrostology since 1927.

Projects have included the response of pastures to fertilizer treatment, the testing of pasture species and strains, the design of seeds mixtures, the improvement of pasture plants by selection and breeding, associated growth and competition in pastures, mineral deficiency problems, the development of scrub lands in areas of relatively liberal rainfall, regeneration and establishment under conditions of low rainfall, and the management of pastures.

1. TOP-DRESSING OF NATURAL PASTURES.

A permanent field experiment to determine the effects of equivalent dressings of phosphate (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, rock phosphate, and the effect of nitrate of soda (78 lb. per acre) added to the superphosphate, has been maintained continuously since 1925. The effects of each fertilizer on the yield of herbage and the stock-carrying capacity over sixteen years are summarized in Table 10 on page 78.

Since 1940, separate flocks of sheep have been grazed on these plots and on two adjoining plots of sown pasture. On one of the latter, portions have been cut each year for feeding back in the following autumn and early winter. The carrying capacity, live-weight increases and wool production of the sheep have been measured each year. The results are given in Table 11 on page 79, and these show that the live-weight increase and wool production per sheep were as great on the unfertilized pasture as on the top-dressed pastures and the seeded pastures. The carrying capacity was lowest on natural pasture where phosphate had not been applied, and was highest in the case of the seeded pastures.

2. THE RELATION BETWEEN RAINFALL AND THE YIELD OF NATURAL AND SEEDED PASTURES.

Regression analysis of the relationship between the annual yield of natural pasture and rainfall throughout the season has indicated that the yield of this type of pasture is largely predetermined by the amount of autumn and early winter rainfall.

Similar analysis, applied to the annual yield of seeded pasture composed of *Phalaris tuberosa*, Wimmera rye-grass, and subterranean clover has not revealed any significant relationship between this type of pasture and the annual rainfall or any seasonal fraction of the latter, over a ten years' period. The precise factors responsible for the yearly fluctuations in the yield of seeded pasture of this type have not yet been defined.

3. TESTS OF PASTURE SPECIES AND STRAINS.

The introduction and testing of new species and strains of herbage plants has formed part of the work on pasture improvement since the inception of the Institute. This has led directly to the commercial use in South Australia of *Phalaris tuberosa*, certified perennial strains of rye-grass (*Lolium perenne*), Kikuyu grass (*Pennisetum clandestinum*), Dwalganup and Bacchus Marsh subterranean clovers (*Trifolium subterraneum*), barrel medic (*Medicago tribuloides*), Palestine strawberry clover (*T. fragiferum*), and perennial veldt grass (*Ehrharta calycina*).

Several species of *Trifolium* and *Medicago* introduced through the United States Department of Agriculture in 1940 have grown well at the Waite Institute and are being grown experimentally in parts of the State where they appear most likely to be of commercial value.

Grazing tests carried out on giant star grass (*Cynodon plectostachyum*) have not revealed any harmful effects on sheep grazing on this grass.

Observations have been continued on rhizomatous types of lucerne, collected mainly in South Australia, and on seed-producing strains of Kikuyu grass introduced from Kenya in 1940.

The more important dry-land grasses of the United States were grown at the Waite Institute in 1941, a year of liberal rainfall, but proved unadapted to the Adelaide environment.

4. EFFECT OF SUPERPHOSPHATE AND SURFACE CULTIVATION ON A SEEDED PASTURE.

A permanent pasture of *Phalaris tuberosa* and Dwalganup subterranean clover established in 1936 at the Waite Institute has been subjected since 1937 to dressings of 0, 1, 2, and 3 cwt. per acre of superphosphate, with and without cultivation of the pasture in autumn. The investigation has been carried out over six seasons under six-weekly grazing by Merino sheep.

The yields recorded in 1941 and 1942 have confirmed previous findings, namely, that annual dressings of 1 cwt. per acre (45 per cent. standard) are likely to be sufficient, even for high yielding pasture, provided liberal dressings of phosphate have been applied in earlier years, as in the present case.

At no stage has cultivation of the pasture made any difference to its yield or composition.

The results of the experiment are set out in Table 12 on page 80.

5. DEVELOPMENT OF SEEDED PASTURES IN AREAS OF HIGHEST RAINFALL.

The areas of South Australia with a mean annual rainfall exceeding approximately 20 inches are characterized by much diversity of soil, and attempts to develop pasture on these soils have presented numerous problems. Investigations of these problems have been conducted in co-operation with the Council for Scientific and Industrial Research.

In 1942 exploratory trials were established over a wide range of soil types, and in addition, representative samples of soils not covered by field experimentation were brought to the Waite Institute for investigation in pot cultures. This work has been designed to enable the problem of pasture development in these areas to be studied on a regional basis.

Field investigations were conducted on 16 properties and a range of 26 soils was examined in pot cultures.

(1) *Adaptability of Herbage Species and Strains.*

Seven of the standard field crops, 13 grasses, and 28 herbage legumes were sown at the different country centres and their behaviour under varying fertilizer

treatments noted. The factors of strain and of cultural treatment have also received attention. Suitable species and strains of herbage plants appear to be available as a basis for the establishment of permanent pasture in these areas, but it is evident that there is scope for considerable improvement of pastures by the further introduction, selection, and breeding of herbage plants.

(2) *Survey of Deficiencies.*

In each of the field trials, selected species and strains of grasses and clovers have been grown in the presence and absence of all the known essential nutrients, as well as a number not proven necessary for plant growth. Subterranean clover and lucerne have been the principal test plants employed for the study of deficiency problems in pot cultures. Response to single elements or to mixtures of elements has been taken as the main criterion of soil deficiency.

Responses to "minor" elements have been obtained in the field at Robe, Rendelsham, Mount Benson, Naracoorte, Wood's Well, Meadows, Houghton, and Waitpinga. The effect of copper and zinc on peat soil at Rendelsham was noteworthy; a yield of subterranean clover eleven times that from plots receiving superphosphate only was obtained. The result has a bearing on the projected development of similar soils at Eight Mile Creek, which have responded to minor elements in pot cultures.

Although responses to minerals did not occur at some centres, evidence of response to wood ashes was obtained in most cases. In 22 out of 26 soils examined in pot cultures, significant responses to minor elements were recorded. Investigations designed to determine the factors concerned in these responses are proceeding.

(3) *Detailed Studies at Specific Centres.*

(a) *Robe.* Confirmatory evidence of the need for dressings of copper and zinc on the Robe calcareous sand was obtained in 1942. Studies of the residual effects of these elements, when applied as fertilizers, are in progress. There is a strong residual effect of applied copper.

(b) *Meadows.* The marked effect of wood ashes previously noted on ironstone soil has been shown in field experiments to be due to molybdenum, and marked increases in the yield of lucerne and subterranean clover have resulted from applications of this element to the same soil in pot cultures. Experiments to determine optimum rates and frequencies of application are being carried out. Good results have followed the application of one ounce per acre of molybdenum-bearing salts.

Experiments were commenced in 1942 to study the role of molybdenum in the nitrogen nutrition of herbage legumes. Investigations are also being conducted to determine the factors concerned in the responses obtained with lime on this soil.

(c) *Wood's Well.* The particular need for heavy dressings of phosphate on heath plain in this area has been amply demonstrated. Experiments are in progress to determine the amounts of superphosphate required, the conditions under which the most effective use of phosphate is made, and the extent to which residual effects persist following the application of copper sulphate. Responses of lucerne to copper obtained in 1941 persisted the following year without further dressings of copper.

Tangier pea (*Lathyrus tingitanus*) was the most productive fodder crop of those tested and may prove of value as a pioneer legume on this soil. Perennial veldt grass (*Ehrharta calycina*) and *Phalaris tuberosa* appear to be suitable perennial grasses for the region. Bacchus Marsh subterranean clover was the most successful herbage legume.

(d) *Kangaroo Island.* A series of experiments was commenced on the sandy

soil of the lateritic peneplain of Kangaroo Island in 1941 on portion of an area of 500 acres, the development of which was undertaken by the Department of Lands.

The reserve of copper available in the soil was apparently sufficient for full development of subterranean clover in the first year, during which the growth of the clover was not improved by a dressing of $3\frac{1}{2}$ lb. copper sulphate per acre, but was suppressed by the addition of 7, 14, or 28 lb. of copper sulphate per acre. Excessive moisture as a result of sowing on fallow led to poor results with peas, but this crop responded to $3\frac{1}{2}$ lb. per acre of copper sulphate; the crop was depressed by higher amounts.

The leguminous species were more readily injured by increasing dressings of copper than were the grasses. Oats and Wimmera and perennial rye-grasses were not injured by applications up to 28 lb. per acre. The yield of the grain in oats was very low under all treatments, indicating a possible deficiency of some element or elements other than phosphorus and copper.

Subterranean clover proved the most vigorous of the legumes and its yield greatly exceeded that of a mixture of cluster clover, barrel medic, and King Island melilot in both 1941 and 1942.

Seeding rates of 2 lb. per acre of perennial rye-grass or *Phalaris tuberosa* did not reduce the establishment and yield of subterranean clover in the seeding year or in 1942.

Subterranean clover and peas both responded vigorously to dressings of 2 cwt. per acre of superphosphate, and the most economic application in the early years of the pasture may exceed this figure.

Lucerne responded in 1942 to the application of lime in the previous season, but it has proved much less productive than subterranean clover.

Bacchus Marsh has been the highest yielding strain of subterranean clover over the first two years of a strain trial.

The need for applied copper became evident in the second season, when the yield of clover was markedly reduced on plots which had not received copper in either year. The residual value of all dressings of copper applied in 1941 was sufficiently high to produce maximum yields. These were secured as a result of the application of $3\frac{1}{2}$ lb. copper sulphate per acre in either year.

Although there was an apparent response to the application of elements other than copper in the first year, no significant response to wood ashes or additional minor elements was evident in the second year.

Application of superphosphate some weeks after the break of the season compared with early dressing, or splitting the total dressing into autumn and spring applications, had no effect on the development of the pasture in 1942. When applied in quantities representing equivalent amounts of phosphate, serpentine superphosphate was found to give results comparable with superphosphate.

(e) *Waitpinga*. Considerable difficulty has been experienced in the maintenance of subterranean clover pastures on the sandy loam soils of the Waitpinga district. A series of trials was commenced on the properties of Messrs. A. Shearer, A. H. Warland, and A. Hannaford in 1941 and 1942. Established pasture in which the development of the subterranean clover was unsatisfactory was treated with various fertilizers in addition to superphosphate. The pasture on both properties showed a response to the application of wood ashes and to sheep manure; superphosphate and copper sulphate improved the growth of clover on one area.

Tangier pea (*Lathyrus tingitanus*) was the most productive fodder crop of those tested and merits further investigation. There was almost a complete failure of oats and peas where no superphosphate was applied. Excessive moisture prevented satisfactory development of peas. No significant effects from the application of minor elements were recorded in the first year of the pasture, in a comprehensive trial.

6. THE ESTABLISHMENT OF PASTURES UNDER COVER CROPS.

The restoration of soil structure and fertility on land depleted by cereal production presupposes the practical replacement of cropping by pasture. The incorporation with field crops of seedings of herbage plants, if successful, enables pasture establishment to be accelerated and costs to be reduced. The competitive effects of the principal crops on different herbage species thus offer scope for investigation.

The establishment of seeded pasture under different cover crops has been studied in field experiments commenced in 1941. Lucerne, subterranean clover, barrel medic, and *Phalaris tuberosa* were sown at varying depth with wheat, oats, barley, peas, linseed, and flax harvested, and with wheat, oats, Wimmera rye-grass, and prairie grass grazed.

The persistence of different species and the yields of the pastures in 1942, resulting from seedings made in 1941 are shown in Table 9 on page 76.

The establishment of subterranean clover and of lucerne sown at $\frac{1}{2}$ -inch depth was as high under linseed yielding 16.44 bushels per acre as in the absence of any cover crop. Seeding at 1 inch depth was less satisfactory for these two species. Maximum establishment of lucerne was also attained under prairie grass (8 lb. per acre) and Wimmera rye-grass ($\frac{3}{4}$ lb. per acre), each yielding 2 tons of dry matter per acre; but the results were not so satisfactory under oats and wheat, harvested or grazed, or under peas, barley and flax harvested. The establishment of subterranean clover sown at $\frac{1}{2}$ -inch depth under grazed oats or barley was as good as or better than under prairie grass, Wimmera rye-grass, or with no cover, grazed in each case. It was the same under harvested oats and barley as under grazed oats and barley, but was poorer under harvested peas, barley, and flax, and reached a maximum under linseed or with no cover (ungrazed). The establishment of barrel medic was relatively poor under all treatments, but was highest under linseed. The establishment of *Phalaris* was highest without any cover, and was lower in the presence of lucerne than where sown with annual legumes. Linseed, then peas, reduced *Phalaris* less than the remaining cover crops. Grazing of oats and wheat improved considerably the establishment of *Phalaris* sown with these two crops.

7. INVESTIGATION OF PASTURE MANAGEMENT, WAITE INSTITUTE.

A top-dressed pasture of *Phalaris tuberosa*, Wimmera rye-grass, and Dwalganup subterranean clover, established at the Waite Institute in 1936, has been subjected to differential grazing treatment throughout the five seasons 1937-41. In 1942 the cumulative effects of the five years' grazing treatments, comprising all combinations of stocking rates, of 2, 4, and 6 sheep to the acre, with grazing at 3, 6, and 9 weekly intervals, together with no cutting for hay and cutting for hay, were determined by obtaining the yield of pasture under all treatments in the absence of the grazing animal.

This pasture has shown itself capable of high and sustained carrying capacity over the full period of the experiment, whatever grazing treatment has been applied. The grazing treatment has, however, greatly modified the botanical composition of the pasture, as will be seen by reference to Table 13 on page 80. Under 3-weekly grazing the perennial grass has become weakened and the pasture characterized by a higher content of clover. In the later years, under the heaviest grazing of six sheep per acre, there has been a marked increase in the percentage of inferior plants and weeds. Under light stocking the frequency of grazing has not resulted in any marked detrimental effect on the pasture, and the vigorous development of *Phalaris* and subterranean clover has prevented ingress of weeds. Much greater

root reserves of the perennial grass were present in plots not cut for hay and grazed at two sheep to the acre than in those grazed at six sheep per acre. Three-weekly grazing proved more drastic on *Phalaris* than either six-weekly or nine-weekly grazing. Hay cutting over five years did not reduce the productivity of the pasture to any marked extent, but lowered the root reserves of *Phalaris* substantially under light grazing; under heavy grazing, cutting for hay produced little effect on the reserves. The yield of hay has, however, been reduced from an average of 36.5 to 26.9 cwt. per acre over the five years by increasing the stocking rate from two to six sheep per acre, and from 33.4 to 29.1 cwt. per acre by grazing every three weeks instead of every nine weeks.

8. GRAZING TRIALS AT KYBYBOLITE AND THE WAITE INSTITUTE.

Trials of grazing management on pastures of *Phalaris tuberosa*, Wimmera rye-grass, and subterranean clover were commenced at the above two centres in 1940 and were continued in 1941 and 1942. At each centre an area of 21 acres was subdivided into 16 equal plots, eight of which have been grazed continuously and eight rotationally at eight-weekly intervals in the autumn and winter and four-weekly intervals in the spring and summer.

Of each series of plots, four have been cut for hay and four not cut. Two of the four plots of each hay section have been mown in late spring of each year and the herbage fed back to the sheep during the summer and autumn months over all the four plots of the series. Four groups of sheep made up of equal numbers of Merino and Romney Marsh-Merino crossbred wethers were allocated to each series of four plots so as to be equivalent to a carrying capacity of four sheep to the acre. Owing to the extremely unfavourable climatic conditions of the initial grazing year (1940) the stocking rate was reduced and stabilized in 1941 at 3.2 sheep per acre at both centres.

The weights of the sheep have been measured monthly and data on the weight and count of the wool recorded each season, together with an assessment of the value of each fleece.

During the years 1941 and 1942 there were no significant differences in live-weight or wool production between the sheep grazed continuously and those grazed rotationally. Feeding hay over the 1941-42 summer increased the live-weights of crossbred sheep at both centres but improved the live-weight of Merino sheep at the Waite Institute only. Differences in the weight and value of the wool at both centres in 1941 were insignificant, but the crossbred sheep at the Waite Institute in 1942 produced an average of 2 lb. 5 oz. more wool per head where hay was cut and fed back. This was valued at three shillings more per fleece. At Kybybolite feeding has made no difference to the wool production of the crossbred sheep. At both centres the improvement in the wool produced by Merino sheep given hay was valued at one shilling per head. The production of hay in 1942 was much greater at Kybybolite than at the Waite Institute, but the mean live-weights of all sheep were materially greater at the Waite Institute. At both centres the continuously grazed plots produced over 16 cwt. per acre more hay than those grazed rotationally.

9. INVESTIGATIONS OF PASTURE MANAGEMENT, YUDNAPINNA STATION.

The preservation and economic use of pastures in areas of low rainfall are closely dependent on their management, and investigations concerning the reaction of shrub-steppe to different kinds of grazing should enable better use of this type of country to be made.

To this end an experiment was undertaken in 1941 on five square miles of blue-bush (*Kochia sedifolia*) and myall (*Acacia Sowdenii*), subdivided into 14 plots of

160 acres each, with two larger reserve areas in addition. Four types of spelling treatment have been employed at grazing intensities of 24, 48, and 72 sheep per square mile. One plot is ungrazed.

The effects of treatment on the pasture are assessed by estimations of the weight of herbage at 64 fixed points once each year. The sheep are weighed monthly and the production of wool recorded following shearing in February.

Ten-month-old wethers were shorn in April and placed on the plots on 1st May, 1941, following a period of liberal rainfall. Drought was experienced from September, 1941, to May, 1942, but winter rains in 1942 led to a vigorous development of bluebush and of many annual ephemeral species. Drought again ensued from October, 1942, onwards.

The amount of herbage available has at all times been adequate for the needs of the sheep, and no significant differences have so far occurred in the mean live-weights of the various flocks. There were no significant differences in the wool production per sheep at shearing in 1942.

Examination of the plots in August, 1942, indicated no differential effects on the pasture up to that time except on one plot that had been grazed at 72 sheep per square mile for 13 months on end. This had led to severe over-grazing of the bluebush. The experiment is necessarily of a long-term character and is not expected to yield major differences immediately.

10. INVESTIGATIONS RELATING TO SOIL EROSION AND PASTURE REGENERATION.

(1) *Pastoral Areas.*

Detailed studies of denuded areas, protected from sheep and in part from rabbits, have shown that natural regeneration can only occur with extreme slowness owing to the low and unreliable rainfall of the pastoral areas. Artificial seedings of saltbushes, bluebushes and various other species, carried out under favourable conditions in 1939, proved to be almost a complete failure. Regeneration of mulga (*Acacia aneura*) has been shown to occur on over-grazed areas when these are protected from both rabbits and sheep.

The effect of grazing, in causing deterioration of the plant cover and subsequent erosion of the soil, is being investigated in the trial described in the previous section.

Ploughing of contour furrows on a denuded slope at Blanchetown, followed by seeding to saltbush (*Atriplex vesicarium*), bluebush (*Kochia sedifolia* and *K. Georgei*), barrel medic (*Medicago tribuloides*), and Wimmera rye-grass, enabled the soil moisture supply to be augmented sufficiently to permit establishment of perennial species and seed production by the annuals.

(2) *Murray Mallee.*

Trials with numerous native and introduced species of herbage plants were commenced on fallow at Pallamana in 1937. The adaptability of the native saltbush and blue-bush species to the area has been clearly demonstrated, and their dominance over the introduced species has become accentuated as the investigation has progressed. Some of the native saltbushes in particular have regenerated vigorously from seed.

The value of creeping lucerne on sand drift, following stabilization by rye corn, has been exemplified by abundant development of rhizomes and of surface cover by this plant. The lucerne has responded to copper sulphate applied in addition to superphosphate to the drift.

11. PASTURE ESTABLISHMENT IN CONJUNCTION WITH CROP ROTATION AND LAND USE, PALLAMANA.

To investigate the possibilities of utilizing more effectively marginal crop lands, a long-term rotation experiment was commenced at Pallamana in 1939. The experiment covers seven acres, and includes 64 plots in eight rotations.

Wheat is the main cash crop in each rotation; oats is sown for grain in two rotations. The maximum number of grain crops in an eight-year period is four. In four rotations, a seeded pasture mixture of lucerne, perennial veldt grass, barrel medic, and Wimmera rye-grass has been sown alone or with wheat or oats and occupies the land for at least five years. In one rotation, creeping saltbush and barrel medic are seeded down for a period of three years.

The seeded pastures did not outyield the natural pastures during the three seasons 1939-41, but produced more than the latter under conditions of relatively high rainfall in 1942. The seeding of creeping saltbush and barrel medic has led to higher yields than the pasture mixture described above. High yields of both saltbush and lucerne followed heavy summer rainfall in January, 1941.

Top-dressing with superphosphate has not proved effective in increasing the yield of natural pasture. Associated cover crops have lowered the establishment and subsequent production of the sown pastures.

The yield of wheat was substantially reduced by rust in 1941. In 1942 wheat averaged 27 bushels and oats 51 bushels per acre.

4. WEEDS AND WEED CONTROL.

Investigations of the single-leaved cape tulip (*Homeria collina*) and two-leaved cape tulip (*H. miniata*), commenced in 1940, were discontinued in 1942 owing to the enlistment of staff. Evidence from experiments carried out in pot cultures and in the field has indicated that the problem in each case is essentially an ecological one, and that satisfactory control can be secured by cultivation and cropping, followed by the establishment of suitable pasture mixtures.

In the case of both species, plant competition has proved the most important factor in causing a reduction in the growth of cape tulip. Both grasses and legumes, if suitable in other respects, appear to be effective provided soil conditions are favourable for their development. A high level of available nitrogen in the soil has exercised a strong controlling effect, by reducing corm production, but more particularly by stimulating the competitive influence of sown grasses.

It follows that suitable soil preparation, followed by the establishment of mixtures of permanent legumes and associated grasses in conjunction with appropriate fertilizer treatment, is likely to prove the most effective means of controlling cape tulip. This principle has been successfully applied on an extended practical scale at "Anama," Clare, where major increases in production have accompanied the suppression of the single-leaved tulip. On the northern parklands at Adelaide, control of the two-leaved tulip has been attained similarly, in field plots. Where cultivation of the land is not possible, the encouragement of herbage plants by surface seeding, top-dressing, and grazing management would be expected to assist in the control of these weeds.

5. BOTANICAL SERVICE.

The botanical section of the Department of Agronomy provides for the accurate identification of plants, the maintenance and development of a reference herbarium, and attention to the arboretum, which has an important demonstration value.

An advisory service is supplied to the Minister of Agriculture, to the Minister of Afforestation, and to any persons who wish to avail themselves of the service.

The herbarium now includes over 4,800 specimens, each of which has been named, mounted, and preserved from attack by insects.

Approximately 570 specimens were identified in 1941-42. As a result of the war there have been fewer enquiries relating to weeds and herbage plants, but work concerning species likely to be of pharmaceutical value or to contain commercial substances rendered scarce as a result of the war, has increased.

The largest group of enquiries has arisen from public interest in latex-bearing plants as possible sources of rubber. The following species were repeatedly submitted: cotton bush (*Asclepias rotundifolia* and *A. fruticosa*), dodder laurel (*Cassytha melantha* and *C. pubescens*), false caper (*Euphorbia terracina*), garden Poinsettia (*E. pulcherrima*), garden spurge (*E. dendroides*), a native Euphorbia (*E. eremophila*), undetermined garden plants of the same genus, Moreton Bay fig and other species of fig (*Ficus* spp.), stinkwort (*Inula graveolens*), prickly lettuce (*Lactuca scariola*), native milk bush (*Sarcostemma australe*), and various latex-bearing composites. Although the majority of these species were conspicuous for their latex, they were found to contain either no rubber or such small amounts as to be valueless for commercial extraction.

The following weeds appear to have spread considerably in recent years: poverty weed (*Centaurea repens*), long-fruited wild turnip (*Brassica Tournefortii*), Ward's weed (*Carrichtera annua*), London rocket (*Sisymbrium Irio*), *Galenia secunda*, garden cress (*Lepidium sativum*).

Plant Physiology

In the past, growth studies with cereals, pasture grasses, and tobacco have been the central feature of the work of the Department. Experimental treatments have included variation in the supply of nitrogen, phosphorus, and of water, the latter being withheld in such a way as to simulate drought. The effects of these treatments are naturally of interest in themselves, but the data are also of great value for the advancement of our knowledge of the principles governing growth and development in plants.

The tobacco investigations have aimed at gaining a fundamental knowledge of the plant which would be of value in understanding the cause of poor quality in much Australian-grown leaf. The third experiment of this series is discussed at some length below. More recently, growth studies with flax and linseed have been completed; they, too, have a direct bearing upon practical agricultural problems.

1. STUDIES OF THE FLAX PLANT.

In 1941 parallel experiments were conducted with flax and linseed, the varieties used being Liral Crown and Punjab respectively. In both cases the physiology of growth was studied in some detail and the results were of great value in interpreting the effects of artificial drought applied from the time of commencement of flowering. In both experiments the growth of the plant was depressed by this low moisture treatment, and the growth analyses revealed that this was due to a depression of the net assimilation rate (expressed on a protein basis). These effects were reflected in the yields of fibre and of oil, both being decreased by approximately 40 per cent.

Perhaps the most striking feature of the work on Liral Crown flax was the study of the developmental anatomy of the fibre bundles. This involved the preparation and examination of a large number of cross sections of the stem at each of eight stages of growth. A cross section of a mature flax stem has four main regions, which are clearly shown in Figure 1 on the accompanying plate. They are (a) an outer layer of cells forming the epidermis, (b) a ring of fibre cells arranged

in groups or bundles, (c) an inner ring of woody tissue technically known as the "shive," and (d) the pith, which is hollow apart from remnants of thin-walled tissue attached to the wood.

The number of fibre cells in a cross section of the stem increases with the age of the plant. In plants a few weeks old the fibre bundles consist only of a single layer of cells, whereas in a mature plant they may be four to five cells deep. The outer layer of cells is the first to develop the characteristic thickening of the cell walls, and this process takes place progressively towards the inner boundary of the fibre bundle (see Figures 3 to 6). The effect of the low water treatment is illustrated in Figure 2, where the number of cells per bundle at maturity is seen to be greatly reduced. This reduction in cell number is due to an interruption in the normal development of the bundle consequent upon a deficient supply of sugars for the formation of cellulose. The large thin-walled cells on the inner side of each bundle would doubtless have become typical fibre cells had carbon assimilation been unaffected by treatment.

A point of practical interest is that plants grown with an adequate water supply give a higher percentage weight of fibre in the straw than plants subjected to partial drought after flowering. This implies that straw produced under dry finishing conditions will not yield the same quantity of scutched fibre as straw produced under good finishing conditions. Field trials at this Institute have shown that early sowing is essential for maximum yield of straw, and, since the low water treatment of the above experiment is more or less equivalent to late sowing in the field, the physiological study here reported has a bearing upon that finding.

2. STUDIES OF THE TOBACCO PLANT.

The third and final experiment of the physiological investigations of the tobacco plant was carried out in the 1939-40 season, but much of the analytical work connected therewith was done during the period covered by this report. The tobacco work, which had been undertaken on behalf of the Council for Scientific and Industrial Research, was terminated in 1942 but, owing to the untimely death of Dr. Petrie, it has not as yet been possible to prepare the extensive data of the experiment for publication.

The experiment was designed to investigate the effects of temporary and permanent drought on the growth of the plant and the quality of the leaf. The primary treatments were as follows:

- (1) Controls with high water supply.
- (2) Plants under permanent low-water conditions.
- (3) Plants subjected to low-water conditions for ten days in early growth.
- (4) Plants subjected to low-water conditions for ten days somewhat later.

All these treatments were established in relation to the moisture equivalent and permanent wilting percentage of the soil mixture used.

The plants with permanent low water supply were stunted, and had small leaves of a deep green colour. Ripening of these leaves was much delayed and was so uneven as to make it difficult to determine the optimal time of picking. In comparison with the controls, the early temporary drought resulted in a 20 per cent. increase in the maximum dry weight of the total leaves and a similar, though slightly smaller, increase in all other parts of the plant. The maximum leaf area was increased by 36 per cent., but the time of ripening of the leaves was not appre-

THE FLAX STEM AS SEEN IN CROSS SECTION.

Figures 1-2 are magnified by 40 and Figures 3-6 by 200. Figure 1 shows the structure of a mature flax stem grown with an ample supply of water. Figure 2 shows a similar stem grown with a limited supply of water. Figures 3-6 illustrate the development of the fibre bundle, the stems being 64, 98, 118, and 161 days old respectively.

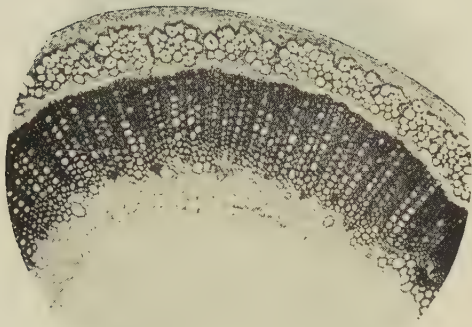


Fig. 1.

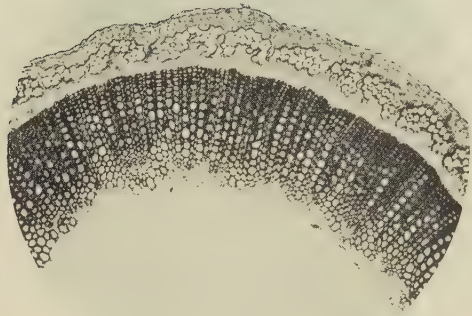


Fig. 2.

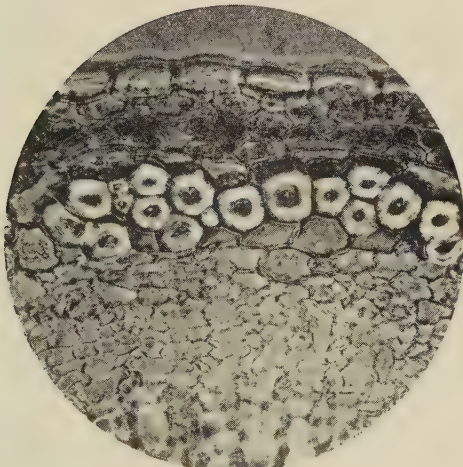


Fig. 3.

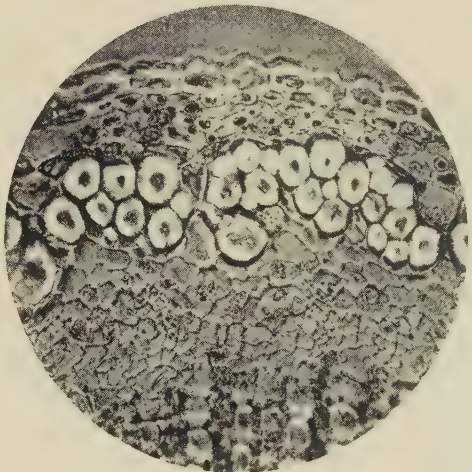


Fig. 4.

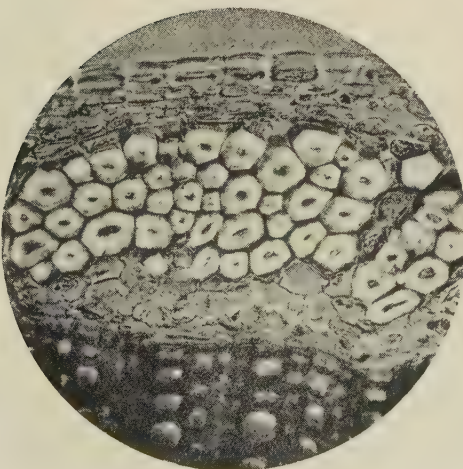


Fig. 5.

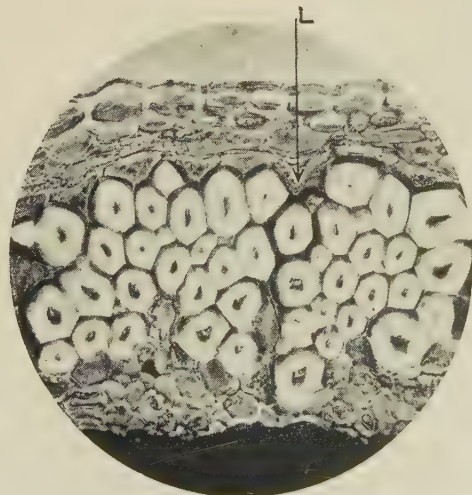


Fig. 6.

ciably affected. The late temporary drought produced a temporary depression in both dry weight and leaf area, but there were no subsequent increases by comparison with the controls. A possible explanation for the effects of early temporary drought is that the increased concentration of the soil solution when water was deficient resulted in a more rapid intake of nitrogen than in the controls. This suggestion is in accord with the the absolute nitrogen data for the treatments concerned.

The carbohydrates of the leaf groups were estimated in four fractions, (a) hexoses, (b) sucrose, (c) labile polysaccharide reserves, and (d) crude fibre. The labile reserves frequently amounted to 60 per cent. of the total dry weight of the leaf, whereas free hexoses, sucrose and crude fibre were each usually less than 7 per cent. The trends with time in these constituents were somewhat complex, but certain broad treatment differences may be mentioned. Thus, in all leaf groups of the plants with low water supply, the labile reserves were reduced to approximately one-half of the contents found for the control plants. The crude fibre content of the leaves tended to be increased by drought, whether this was temporary or permanent.

The carbohydrate estimations were later extended to a comparison of the composition of the leaf groups before and after curing.

*Carbohydrates in Tobacco Leaf (Middle Group) Before and After Curing.**

	Fresh Leaves.		Cured Leaves.	
	Control.	Permanent drought.	Control.	Permanent drought.
	%	%	%	%
Hexose	4.05	2.20	16.63	8.76
Sucrose	2.70	2.80	7.54	5.39
Labile reserves	52.06	23.00	22.01	4.48
Crude fibre	3.70	4.45	3.65	5.00

* Expressed on a dry weight basis.

The outstanding effect of curing was shown to consist of a break-down of a large portion of the labile reserves, chiefly into hexose, but to some extent also into sucrose. Although this break-down was proportionately greater, the hexose content was still much lower in leaves from plants subjected to permanent drought. The relevance of these findings to the problem of quality in tobacco will be evident when it is known that high hexose content in the cured leaf tends to be associated with good quality. Crude fibre, on the other hand, is regarded as conducive to bad quality. The most important carbohydrate component of the freshly picked leaf is the fraction that has been termed labile polysaccharide reserves, since this represents a potential source of reducing sugars released during curing. The marked effect of limiting water supply upon the amount of these reserves, together with other effects upon the chemical composition of the leaf at the time of picking, tends to strengthen the belief that water supply may be an important determinant of quality in Australian tobacco.

The nitrogen supply given to all treatments of this experiment was adequate for the growth of the control plants; those subjected to permanent drought, however, had more than sufficient nitrogen for their limited growth. The drought effects observed are thus of a type which one might expect to find on heavy soils. When both water and nitrogen are deficient, as on certain light soils, the effects of drought may be of a different character.

Leaf samples from three levels on the stems and from all treatments were cured in an experimental curing barn and, after a brief period for maturation, were submitted to smoking tests. On an average, the tobaccos were so poor that comparative smoking quality differences were almost negligible. Many factors may have contributed to this unsatisfactory result, but the fact that the tobacco

was glasshouse-grown is significant. Experiments of the type described above could not, however, be conducted in the field, and their value for the establishment of fundamental principles underlying the determination of important leaf constituents still remains.

3. CROP PHYSIOLOGY.

All growth studies hitherto reported were conducted under the relatively controlled conditions of the glasshouse. This degree of control over such factors as water supply and manurial treatment, together with the fact that root systems could be recovered and weighed, made it possible to subject plant growth to precise analysis, and to separate certain elements peculiar to the species or variety under consideration from others which were directly dependent upon the environment.

During the period under review, the work had reached a stage at which it seemed profitable to apply our methods to a field-grown crop. Only by tackling problems in the field as well as in the glasshouse and laboratory can plant physiology be of direct assistance to the science of crop husbandry.

The first experiment, necessarily of an exploratory character, was conducted during 1942, and the new variety of wheat named Warigo was sown both early and late. The sowing dates were five weeks apart, and both crops were sampled at weekly intervals from the first leaf stage until full maturity. In all, 720 samples were taken, and separate dry weights were determined for leaves, stems, ears, and grain. Estimated grain yields at maturity were 45.9 and 37.9 bushels per acre for early and late sown wheat respectively.

Plant Pathology

Modifications in primary production to meet the needs of a wartime economy have brought changes in the demand for information sought through the advisory service in Plant Pathology. It is mainly the largely increased acreage now being devoted to flax and the added attention to vegetable production that has effected this change.

Up to date the position with regard to diseases in flax has been quite satisfactory. "Rust" (*Melampsora lini*) has occurred, but the damage to the fibre-producing varieties Liral Crown and Concurrent has been slight, even during the 1941 season when the weather favoured what, for South Australia, was a very severe outbreak of rust in wheat. Another disease to attract attention has been a "die-back", limited in distribution and apparently due to a nutritional deficiency. It is referred to more fully below.

In vegetables no diseases beyond the usual variety have been recorded.

Among other plants, three diseases, each of which is suspected to be due to a virus, were recorded for the first time in South Australia. They are "stripe" in daffodils, a "blight" in Williams Favourite cherries, and a disease in Eureka lemons characterized by sectorial grooving on the fruits. A feature of the blight in the cherries was the very rapid withering of leaves and blossoms shortly after flowering. This was associated with branches, or even the whole tree, dying rapidly. The disease occurred in trees which had had scions (Napoleon-Beauchamp's Black) grafted on them for purposes of interpollination. A trouble similar to that affecting the Eureka lemon trees has been observed in New South Wales. Experiments to test whether these two diseases can be transmitted by budding or grafting are in progress.

An interesting disease causing the destruction of considerable areas of false caper weed (*Euphorbia terracina*) was observed in 1942. This weed is established over an extensive tract in a relatively dry area of mallee country near the River

Murray. The essential feature of the disease is a root rot, and is apparently due to a parasitic fungus whose identity, however, has not yet been ascertained. The winter season of the year in which this disease was observed was exceptionally wet, and this fact is thought to have contributed to the epidemic character of the disease.

The 1941 season was notable for a severe epidemic of "rust" in wheat. Judging by estimates made early in spring, the final yield was reduced through rust to about 80 per cent. of that which was anticipated. The season throughout the State was marked by abnormally heavy rain at the end of January, and this was followed by substantial rain in March. These events promoted an unusually abundant growth of volunteer wheat which was well established before the usual seeding time of May and later. In 1942 the latter part of April and the earlier half of May was dry. In some of the earlier districts, however, seeding was completed before the end of April. In all cases where these crops were seen, damage by rust in early spring was already severe. By harvest time it was evident that these early sown crops, which it was suspected had contracted infection in autumn, suffered much more damage than those seeded a month later. In later districts the degree of infection followed the usual course; wheat maturing late, whether by reason of variety or the district, suffered the most. The widespread nature and severity of this epidemic drew attention to the value of rust-resistant varieties, the work upon which is referred to in the section devoted to plant breeding.

1. FIELD CROPS.

(1) *Wheat.*

The disease commonly known as "take-all" or "haydie", in which the most striking symptom is a rapid and widespread development of "white" or "dead heads" with little or no grain, continued to be an important object of investigation. The fungus *Ophiobolus graminis*, which is usually recognized as the cause of "take-all," can cause this damage, and a variety of pot experiments in which this fungus has been used for inoculation purposes have been conducted. The nutritional needs of the fungus when grown in pure culture in the laboratory have also been studied, particularly in respect to the requirement of vitamin-like substances. Fungi other than *Ophiobolus*, especially species of *Fusarium*, may also under some circumstances, induce the development of "whiteheads," and some attention has been given to them. Although the part played by parasitic fungi in causing this complex disease and their interaction with other organisms in the soil is of undoubted importance, field observations and pot experiments combine to show that non-living elements in the soil, the level in nutrients, and physical conditions in the soil are important factors. The attempt is being made to ascertain how far these complex varying features of soil influence the health and vigour of plants directly, and how far they do so indirectly through their influence on the activity of soil-inhabiting parasitic fungi.

Working along these lines, particular attention has been given to the problem raised by the supply of phosphate, manganese, zinc, and copper in the soil; all of them are substances known on occasion to be deficient in soils or at least present in such forms or amounts that beneficial responses to their application have been secured.

A field experiment at Brooker on Eyre's Peninsula was completed in 1942. This experiment has been carried out in co-operation with the Department of Agriculture and the Division of Plant Industry of the Council for Scientific and Industrial Research, and had as its main purpose a determination of the effects of crop rotation on the incidence of "take-all". Unfortunately the experimental area was subject to a violent windstorm in the summer preceding seeding opera-

tions, and the top soil of many fallow plots was completely denuded in places. This misfortune complicates the interpretation of results, but they indicate that the inclusion of Wimmera rye-grass in the rotation for one or two years exercises a beneficial effect on this class of land.

Another field experiment on an area badly affected by "whiteheads" in 1940 (associated with *Fusarium* sp.) is in progress at Roseworthy Agricultural College, and the whole area is expected to be sown to wheat in 1943 when the results will be observed.

(2) *Seed Dressing of Cereals and Flax.*

The field trials to evaluate seed dressings which were started in 1937 in co-operation with, and using materials supplied by, Imperial Chemical Industries of Australia and New Zealand, Limited, have been continued. The main interest in the earlier trials was in the control of "bunt" in wheat and "stripe" in barley, and the materials tested included some in which either copper, organic mercurial or non-metallic organic compounds were the active constituents.

During the period under review the trials were extended to the treating of flax seed, having in mind particularly the view that seed dressing might help to improve plant establishment by limiting the activity of weakly parasitic soil organisms likely to interfere with germination. The trials also included an investigation of the effects of storing treated seed for periods up to twelve months.

(3) *Flax.*

(a) *Diseases.* The "dieback" disease of flax mentioned earlier affects plants most markedly at an early stage in their growth. The symptoms are most striking when they are six weeks to two months old. The plants are somewhat stunted as the result of the top of the main shoot withering. The lower leaves may also be spotted. There are no evident symptoms on the roots. After the growing tip has died, two secondary shoots arise from the cotyledonary node. The tips of these may also die, but more usually one of these shoots continues to grow but it is finer and shorter than that of corresponding healthy plants. After flowering, differences in height are less evident, but affected plants remain green longer. There is evidence to suggest that their fibre content is less than that of healthy plants. No parasitic organism which might cause this disease has been isolated consistently. In the field the occurrence of the disease is closely associated with the patches of chocolate to dark grey soil, rich in limestone, located in the red-brown earth zone of soils. Similar symptoms to those described above have been induced in flax plants grown in water culture solutions deficient in zinc. In agreement with this result it has been found that zinc sulphate added to superphosphate drilled in with the seed very greatly reduces the proportion of diseased plants and improves the stand correspondingly. Further field trials to confirm these results and to ascertain the necessary rates of application and the most economic type of zinc salt to use are being conducted in conjunction with the Department of Agriculture.

(b) *Dew-retting.* At the request of the Commonwealth Flax Production Committee, observations have been made on the dew-retting of flax as it proceeds under the weather conditions occurring at the Institute. It has been found that retting proceeds quite satisfactorily over the period April to October. It proceeds rather more slowly during mid-winter (July mean temperature 51.3°F.) than during autumn and spring. The investigations which are being conducted in co-operation with the Flax Processing Investigations Section of the Division of Forest Products, Council for Scientific and Industrial Research, also included a study of the influence of varietal and maturity differences in straw and the effects of different rates of spreading. Progress reports have been sent to the Flax Production Committee.

2. HORTICULTURAL PLANT DISEASES.

(1) *Rind Blemish in Stored Oranges.*

The general purpose of work under this project is to ascertain the part played by fungi in the spotting of oranges which have been stored at 40° F. It is part of a wider programme of investigation which several State Departments of Agriculture and the Division of Food Preservation, Council for Scientific and Industrial Research have had in hand for several years but which has been curtailed since the outbreak of war. In the work at the Waite Institute, financial assistance for which was granted by the Council for Scientific and Industrial Research, particular attention has been given to the question of infection of the citrus rind by certain fungi, especially by *Colletotrichum* and a fairly adequate picture of this has been secured for South Australian oranges. Infection occurs prior to the time the fruit is picked; the time and severity varies considerably from year to year, from district to district, from tree to tree, and on different parts of the fruit. It can be reduced by appropriate spray treatments.

Spotting of the fruit, however, does not take place for some considerable time after infection occurs, and depends on the condition of storage during this time. In this condition the infection is described as latent. The histological features of this infection and its production under controlled conditions have been studied.

In respect to the problem of the possible association of these infections with the development of spotting, a considerable amount of information susceptible to statistical analysis has been secured. At the same time there is evidence to show that the physiological condition of the orange, whether due to its maturity, or to treatments such as "sweating" after picking, plays an important part in determining whether or not storage spot will develop. The question of the relation of latent infection to spotting is still receiving attention.

(2) *Tomato Diseases.*

The programme of breeding and selecting varieties which combine disease resistance with good horticultural qualities has been continued in association with colleagues in the Plant Breeding and Genetics Section of the Institute. For glass-house-grown tomatoes, an important local industry, resistance to "leaf mould" (*Cladosporium fulvum*) on the one hand and to the wilt diseases (*Verticillium albo-atrum* and to a lesser degree *Fusarium lycopersici*) on the other, are the outstanding problems for which, with the use of American parent material, a successful issue seems likely. Several strains resistant to "leaf mould" have been secured, and these at present are the subject of further selection for horticultural qualities. Progress with resistance to the wilt diseases has been slower on account of the difficulty of ensuring an adequate occurrence of the diseases, a development which is the necessary basis for selection.

In the field, "spotted wilt" is the most important disease, and some encouragement has been gained for the programme of breeding varieties which, while technically speaking are not resistant to this disease, so tolerate it that their productive capacity is not greatly impaired.

"Spotted wilt" is a virus disease transmitted from diseased to healthy plants through the agency of thrips. The development of a relatively efficient spray mixture for the control of thrips, consisting of tartar emetic and brown sugar dissolved in water, has attracted the attention of workers elsewhere as a means for controlling this disease.

At the Institute two comprehensive experiments were conducted in 1941 and 1942 to test this view. To ensure efficient protection the treated plants were

sprayed twice weekly, starting in some cases with plants in the seedboxes. Spraying reduced the thrips population, and as was to be expected, the incidence of "spotted wilt", but the beneficial effects secured, either in the reduction of diseased plants or in the added weight of marketable fruit as the result of spraying, were insufficient to justify the recommendation of this spray treatment for routine commercial practice in South Australia. The results of the first experiment, which were confirmed by those of the second, have been published.

Entomology

The work of the Department of Entomology during 1941 and 1942 has been to a large extent related to problems associated with the war. The work of the advisory services to the State Departments of Agriculture and Woods and Forests shows a steady expansion, as indicated by the increase in the number of enquiries. These services are most helpful to the work of the Department of Entomology. They keep the research workers in close contact with the field officers of the State Departments, and with the problems relating to the various economic insects in the State. During the past two years advice has been sought, from time to time, from other organizations concerning insect problems of medical importance, and insects of flour mills and stored foodstuffs.

1. INVESTIGATIONS ON WEEVILS IN STORED WHEAT.

As referred to in the last report, detailed investigations have been made on problems relating to weevil infestation of wheat stored in bag stacks in South Australia. An extensive survey was made of wheat storage sheds and stacking sites in various parts of the State, with particular reference to weevil infestation. The results of the survey were embodied in a report to the State Superintendent of the Australian Wheat Board. They showed the measures which should be taken to reduce the chances of spread of weevil infestation. Experiments were made in order to find out a suitable insecticide for treating weevil-infested sheds and dunnage. The results showed that certain oil emulsions, having particular physical properties, could be used for this purpose. A detailed account of the present state of our knowledge relating to "Wheat Storage Problems in South Australia", particularly in relation to insect infestation of wheat in bag stacks, was given in a series of articles in the *Journal of Agriculture of South Australia*, Volume 44. The series was issued later as a bulletin (Reprint No. 314).

(1) *The Environment in Stacks of Bagged Wheat.*

Owing to several reasons which are favoured by organizations concerned with the grain trade in South Australia, wheat has been stored always in bags in this State. In normal times, the bagged wheat at harvest is placed in sheds or stacks at convenient local centres, such as railway sidings, and within a few months it is cleared to millers or to ports for export shipment. Under present conditions, the wheat stored in bag stacks may have to remain in the stacks for several years. The average annual yield of wheat in South Australia, for the decade ending 1939, was 36 million bushels. Holding depots have been established by the Australian Wheat Board at convenient centres for the storage of the surplus wheat. Individual wheat stacks in these depots vary in size. In general, a single stack is about 25 yards wide, and several hundred yards long. It is divided into units of 100 feet long, each unit being separated from the adjacent one by a break six feet wide. The stack wall is 23 bags of wheat high on the high side, and 17 bags high on the lower side. An approximate estimate of the amount of wheat in a stack built in

this way is obtained by allowing four bags of wheat (12 bushels = 720 lb.) per square foot of the area of the stack base. This would represent 2,800 bags of wheat in a unit area of 70×100 feet. It should be noted that 42 per cent. of the volume of a bag stack built in this way consists of air space between the bags and grains of wheat.

The environment in the stack, as determined by the moisture content of the wheat and the temperature and carbon dioxide content of the stack air, has an important bearing on the spoilage of the wheat and its susceptibility to damage by insects. In May, 1941, the Australian Wheat Board built three experimental stacks at the Waite Institute so that regular observations could be made on these matters. Each stack measured approximately $12 \times 12 \times 12$ feet, and contained 480 bags of wheat.

Stack I consisted of 480 bags of F.A.Q. wheat having a moisture content of 11.5 per cent. when stacked.

Stack II had a central layer of 160 bags of wheat which had been conditioned to a moisture content of 15 per cent. at the time of stacking. The remaining bags in the stack contained F.A.Q. wheat having 11.5 per cent. moisture as in Stack I.

Stack III had a central core of 70 bags of wheat well infested with the weevil *Calandra oryzae*. The remaining bags in the stack contained F.A.Q. wheat having 11.5 per cent. moisture as in Stack I.

Appropriate apparatus was placed in various positions in the stacks at the time of building so that the observations referred to above could be made at frequent intervals: twice weekly. Similar observations were made also in certain depot stacks, at a longer interval of time, usually monthly. The records are being continued until June, 1943, that is, over a period of two complete years.

(a) *Temperature in the stacks.* Records of the temperature of the stack air, between the wheat grain, are being taken twice each week in the outside bags and at three feet depth and six feet depth in the stacks. The records illustrate the relation between the fluctuations in the temperature of the outside air and the seasonal march of temperature, and the temperature of the stack air. In the inter-grain spaces at one inch depth in the outside bags, the temperature follows closely with the fluctuations of the outside air. At six feet depth in Stack I the temperature throughout the year was on average about 10° F. lower than that in the outside bags: it showed practically no reaction to the daily temperature changes of the outside air, but the general level of the temperature at the end of the winter and of the summer illustrated the effect of the seasonal march in temperature. An average level of about 65° F. was attained during the summer of 1941-42 at this position in the stack but, following a heat wave in February and March, the temperature rose temporarily to 74° F.

At ten feet depth in a depot wheat stack at Kadina the temperature remained steady for relatively long periods. The slight rise in temperature towards the end of the summer indicated the influence of the seasonal march of temperature, but the variation in temperature between winter and summer at this depth in the stack was only about 10° F.

In Stack III temperatures were higher owing to weevil activity. At six feet depth it fluctuated about an average temperature of 70° F. throughout the year.

(b) *Moisture content of the wheat.* Records of the moisture content of the wheat in the outside bags and at three feet and six feet depths in the Waite Institute stacks illustrate the relation between the seasonal march of air humidity and the moisture content of the wheat month by month.

In Stack I the moisture content of all the wheat was 11.5 when stacked in May, 1941. In the outside bags it dropped during the summer, and was 9.5 per cent. in March, 1942. It advanced to 15 per cent. by August, 1942, and had dropped to 10 per cent. seven months later.

At six feet depth the wheat had a moisture content of 11·5 per cent. in March, 1942. It advanced to 13 per cent. in August, 1942, and had dropped to 10 per cent. seven months later.

At fifteen feet depth in a depot stack at Kadina the variation in moisture content was very small. The wheat had a moisture content of 11·5 per cent. in January, 1942; it had increased only 0·5 per cent. by August, and six months later it had fallen again to 11·5 per cent.

When wheat takes in moisture it swells. This affects the relationship between bushel weight and volume of the grain. At the request of the Australian Wheat Board, tests were made of two grades of wheat at different moisture contents by means of chondrometer weighings. The results obtained showed that the bushel weight of the wheat, as determined by chondrometer weighings, falls as the moisture content rises. A sample of wheat classed as weighing 54 lb. to the bushel had a moisture content of 12·3 per cent.; at the time the experimental weighings were made it weighed out at 53 $\frac{3}{4}$ lb. to the bushel. When the moisture content of the wheat was raised to 17·4 per cent., the wheat weighed out at 51 $\frac{1}{2}$ lb. to the bushel.

A sample of wheat classed as weighing 58 lb. to the bushel had a moisture content of 12·2 per cent.; at the time the experimental weighings were made it weighed out at 57 $\frac{3}{4}$ lb. to the bushel. When the moisture content was raised to 17 per cent., the bushel weight dropped to 55 $\frac{3}{4}$ lb. These higher moisture content values are not normally experienced in stored wheat in South Australia, but the selected examples serve to illustrate a principle which is of practical importance in the grain trade, particularly with certain grades of wheat.

(c) *Carbon dioxide concentration.* The carbon dioxide concentration in the air in the wheat stacks at the Waite Institute and in a depot stack at Kadina was determined once a month. This was done by drawing off a suitable amount of air from the required situation in the stack through suitable piping which had been built into the stacks.

The concentration of carbon dioxide in the spaces between the wheat grains in Stacks I and II was practically the same as that of the normal atmosphere (0·03 per cent.). Similar results were obtained for the depot stacks. It was slightly higher (0·4 per cent.) in Stack III due to the weevil infestation. The results show that with F.A.Q. wheat there is no concentration of CO₂ in the intergrain air in the type of bag stacks described above.

(2) *Investigations on the Weevils of Stored Wheat.*

The two most important insects which damage stored wheat in South Australia are the rice weevil (*Calandra oryzae*) and the lesser grain borer (*Rhizopertha dominica*). A considerable amount of general investigational work has been done with these insects in various countries, but precise information under controlled experiments is required about the influence of temperature, moisture, and associated physical conditions in their environment in stored grain on the rate of multiplication of the insects, particularly in stored wheat. Experiments were commenced in 1942 in order to find out the influence of these various conditions in the environment on mating, oviposition, development, and survival of the egg, larva, prepupa, pupa, and adult in these two species of insects with particular reference to the infestation of wheat. The information which has been established has a direct bearing on the "safe" conditions for wheat storage.

The rate of egg laying of *C. oryzae* was determined over the life span of the adult at four temperatures and three different densities of the weevil population. Wheat having 15 per cent. moisture content was used in these experiments. It was found that wheat of 15 per cent. moisture content was more favourable for oviposition than wheat with 12 per cent. or 20 per cent moisture content. A temperature

of 29° C. was more favourable than any other temperature. A density of one weevil in 50 grains was more favourable for oviposition than higher or lower densities of weevil population. Adults were unable to lay eggs at temperatures below 13° C. or above 35° C. They do not lay eggs in wheat having a moisture content of 8 per cent. or lower. At temperatures above 25° C. eggs are laid in wheat at 9 per cent. moisture content, but even then at a very low rate. At all temperatures there was a large difference in the number of eggs laid in wheat at 11 per cent. as compared with that at 10 per cent. moisture content.

The eggs of *C. oryzae* were able to hatch at temperatures ranging from 13° C. to 34° C. At 34° C. only 33 per cent. hatched. The shortest time for development occurred at 29° C. The complete development of the life cycle of the insect from egg to adult was obtained at temperatures ranging from 15° C. to 34° C. At 34° C. only 1 per cent. of the insects was able to complete their development. The time required for development to be completed was longest at 15° C., being eight to nine months. It was shortest at 29° C., being 33 days in wheat of 15 per cent. moisture content. Development of the egg stage at this temperature occupied two to six days, the larva 19.4 days, the prepupa two days, and the pupa eight days. The adults remained three days within the grain before emerging. At the same temperature, but in wheat of 11 per cent. moisture content, the whole cycle took three days longer and the mortality was 20 per cent. The mortality was higher in wheat of 11 per cent. moisture content at temperatures above or below 29° C. At moisture contents below 11 per cent. only very few of the insects were able to complete their life cycle. Mortality due to dryness or unfavourable temperatures was always highest in the first stage larva; most of the larvae surviving that stage were able to complete their development. In a heavy infestation two weevils may be able to complete their development in one grain, less frequently three completed development in one grain. At a density of three insects per grain the larvae developed much less rapidly than at a density of one insect per grain.

Rhizopertha dominica caused extensive damage to wheat stored in bag stacks in South Australia during the World War I period, 1916 to 1918. After 1920, when the accumulated stocks of wheat had been disposed of, the species does not appear to have been recorded in the State. *C. oryzae* remained always in evidence. *R. dominica* reappeared in April, 1941, in wheat stacks at one of the ports. Restricted infestations have occurred in one or two other situations, but up to the present time widespread infestations of the species have not developed. This is doubtless largely due to the measures which have been taken to restrict the spread of the insect.

The temperature range of *R. dominica* was found to be higher than that of *C. oryzae*. The limiting temperatures for hatching of the eggs were 18° C. and 38.6° C. At 38.6° C. the mortality of the eggs was 20 per cent. One-tenth of a degree higher it was 90 per cent. Experiments are in progress to determine the rate of development and the survival rate over this temperature range of the various stages in the life cycle in wheat at moisture contents varying from 6 per cent. to 15 per cent.

2. GRASSHOPPER INVESTIGATIONS.

An extensive programme of research on the small plague grasshopper (*Austroicetes cruciata*) was started in 1937 with particular reference to the ecology of this species in South Australia. In 1938 arrangements were made whereby the Waite Institute should investigate the species throughout its range in Australia. Additional funds for the work were made available through the Commonwealth Council for Scientific and Industrial Research. The progress of the investigation

has been discussed in earlier reports, and various papers on the subject have been written by members of the Department of Entomology.

The investigation has now been completed, and a general account of the information which has been established about this important economic insect will be given eventually in the form of a bulletin.

The distribution of *A. cruciata* is determined by climate. Soil type and vegetation influence the density of its occurrence within its bio-climatic zone. In Western Australia, South Australia, and New South Wales it occurs in a belt of country bordering the area in which wheat can be safely grown. On its southern and easterly sides the limits of the grasshopper belt agree fairly closely with the line where the ratio of precipitation to evaporation equals one for the month during which the eggs hatch and first and second stage nymphs are present (September in South Australia and New South Wales, August in Western Australia). On its dry inland side the limits of the grasshopper belt correspond fairly well with line $R/E = 0.25$ for the month during which the nymphs mature and the adults commence egg-laying (October in South Australia and New South Wales, and September in Western Australia).

The eggs of *A. cruciata* enter a state of diapause shortly after they are laid. While they remain in this state the eggs do not respond normally when placed at temperatures within the favourable range for development of the post-diapause embryo. When eggs collected shortly after they were laid were exposed at 35°C ., no appreciable development had occurred even after six months. At 30°C . very slow development could be detected, and the embryo required six months to reach a stage of development which *Melanoplus* (an American grasshopper in which diapause is present) reaches after nine to ten days at 25°C .; but none of the embryos developed beyond this stage although most of them remained apparently alive for twelve months. At 20°C . development was able to progress a little further; after six months most of the embryos had developed to the end of anatrepsis (a stage reached by *Melanoplus* after 21 days at 25°C .), and after twelve months 0.4 per cent. of the eggs had produced nymphs.

For the elimination of diapause the eggs required to be exposed to low temperature for an adequate period, when the embryo is at a suitable stage of development. With eggs of *A. cruciata* collected in eastern Australia, diapause is eliminated most rapidly at 10°C ., and somewhat less rapidly at 13°C . and 6°C . With eggs of *A. cruciata* collected in Western Australia, 13°C . was found to be the most effective temperature for eliminating diapause, followed by 10°C . and 6°C . in that order. This indicates a difference in the species in the two areas.

The occurrence of diapause in the egg stage is an important adaptation enabling the grasshoppers to maintain a relatively high density in the climatic zone in which they occur. In this zone the spring is the only period of the year when an abundance of food occurs in conjunction with temperature adequate for post-embryonic development of the grasshopper. The presence of diapause inhibits development during the summer and autumn, and ensures that the eggs hatch in the spring after they have been exposed to the relatively low temperature prevailing during the winter.

Fluctuations from year to year in the numbers of grasshoppers are causally related to the weather. The ovaries of a female *A. cruciata* may contain 270 ovules, sufficient if they all mature for about 14 egg-pods. It is rare for a grasshopper to lay this many egg-pods since the plants upon which the insects depend for food usually dry off and the grasshoppers die from starvation before this potential is realized. In most years most of the grasshoppers which reach maturity live long enough to lay several egg-pods. But in some years (e.g. 1940 in South Australia) rainfall in the winter and spring may be so inadequate, and the supply of food

so short, that most of the grasshoppers die without reaching the egg laying stage. Droughts as unfavourable as that in 1940 probably occurred five to ten times (depending on the district) during the past 50 years in South Australia.

Other factors affecting the survival rate of *A. cruciata* in the field include the influence of summer drought on eggs in diapause. Eggs are particularly resistant to desiccation when they are in the diapause stage. Nevertheless a prolonged hot, dry spell, as in the summer of 1938-39, may destroy a large proportion of the eggs. Mortality of eggs equivalent to that observed at Hawker in the summer of 1938-39 probably occurred from 0-5 times (depending on the district) during the past 50 years. Drought coinciding with the period when nymphs are due to emerge from the pods may cause heavy mortality. The probability that a six-day drought will coincide with the peak emergence of nymphs is 1.2 per cent. for Hawker (one of the driest areas in the grasshopper belt), i.e. mortality from this cause may be expected to be heavy about 12 times in a thousand years. Excessive humidity during the period when the nymphs are about may also operate to reduce grasshopper numbers. The operation of this factor has not been demonstrated directly for *A. cruciata*, but it may be inferred from an ecological study of the distribution of this species in Australia.

In Western Australia the area normally supporting plagues of *A. cruciata* was extended considerably to the west and south during 1937. On this occasion plagues developed temporarily in an area normally too humid to support plagues; this was associated with a period of abnormally dry seasons.

Increase of the abundance of *A. cruciata* in certain areas of Western Australia and South Australia is causally related to the history of land use in these areas, and this probably applies to New South Wales also. The country was first opened up for wheat. After producing wheat profitably for a number of years, it was abandoned for wheat growing and subsequently developed for sheep raising. The pastures contain plants which established themselves "naturally" after the land ceased to be cultivated; they are dominated by low annuals. These pastures provide ideal breeding grounds of *A. cruciata*. There are two other unfortunate consequences of using this type of pasture in an area which experiences a low and uncertain rainfall. Violent fluctuations in the carrying capacity of the pastures are reflected in violent fluctuations in the numbers of sheep, and this causes serious economic difficulties for the farmer. Also serious and progressive surface erosion is inevitable. Erosion is at a maximum during dry periods when protective cover for the soil may scarcely occur. The sheep pulverize the surface of the soil and the wind blows it away.

The presence of grasshopper plagues aggravates both these disabilities, for the competition from grasshoppers is most serious during poor seasons. The solution of the whole problem lies in the establishment of edible perennial shrubs in the pastures in the grasshopper belt. For this, research in pasture regeneration in these areas is necessary.

3. INSECTS OF AGRICULTURAL AND HORTICULTURAL CROPS.

The webbing caterpillar, larva of the Pyralid moth (*Loxostege affinitalis* Led.), occurred in plague numbers in various parts of the State during January and February, 1941. Fortunately at this time of the year much of the cultivated area is in stubble or fallow, but the caterpillars did some damage to garden crops and some perennial plants in natural pastures. This is the first record for the occurrence of this species in plague proportions in this State, although it has been recorded on several occasions in parts of the eastern States.

The green vegetable bug (*Nazara viridula* L.), which appears to have been first recorded in Australia in 1916, has become well established in South Australia during the past five years. It is present in the Adelaide districts and in a part of the irrigation area on the River Murray. The wasp parasite (*Microphanurus basalis*), which parasitizes the eggs of the bug, was introduced into South Australia at the end of 1942 with the helpful co-operation of the Departments of Agriculture of New South Wales and Western Australia.

Through the helpful co-operation of the Division of Economic Entomology of the Commonwealth Council for Scientific and Industrial Research, a wasp parasite (*Comperiella bifasciata*) of the red scale of citrus was obtained in December, 1942. This is a Chinese parasite of the red scale which the Division recently obtained from California. The work on both these parasites is in progress.

The cabbage white butterfly (*Pieris rapae* L.), which was first recorded in South Australia in 1940, has now become well established in various parts of the State.

4. STUDIES ON INSECT ECOLOGY.

Various studies on problems of insect ecology relating to the influence of climate and weather on the distribution and multiplication of insects which have been going on in the Department for several years, are being continued. During the period under review, our understanding of the meaning and significance of "diapause" in the eggs of grasshoppers has been clarified by the results obtained with the development of eggs of the grasshopper *A. cruciata* in experiments in which temperature and humidity were carefully controlled. Studies on the relation of temperature and moisture to the rate of embryonic development in certain insects have been made. Studies on various insects of economic importance in South Australia have enabled us to understand how "weather" determines the density of the population of these insects from year to year.

5. MISCELLANEOUS.

A general investigation of the habits and life history of the Australian bush fly (*Musca vetustissima* Walk.), was made in 1942. Field observations have shown that the species breeds freely in cow dung during November to May in the Adelaide district. From two brief tours in the northern pastoral country no definite evidence was obtained as to where the flies breed in the arid bush country. In laboratory technique for breeding the flies in captivity it was found that "wild" bush flies can be kept alive in cages up to 40 days on a diet of honey and water: four individuals lived for 80 days. Eggs were laid on cow dung by flies fed since emergence on this diet, but in most cases they failed to develop: out of a total of 326 eggs only six developed through to adult flies. In experiments in which puparia of the bush fly were placed in dry atmospheres at 30° C. and 18° C. respectively, flies emerged from 30 pupae out of 32 at 30° C. and 101 out of 120 at 18° C.

A poison flour paste bait for use in controlling the common household silverfish (*Ctenolepisma longicaudata* Esch.), has been used with success in dealing with a silverfish infestation in the Waite Institute. The following formula was used: plain wheat flour, 4 oz.; sugar, 4 oz.; salt, $\frac{1}{2}$ oz.; sodium fluosilicate, 1 oz. (finely powdered); gelatine, $\frac{1}{2}$ oz., water 3 pints. The flour is made into a smooth paste with part of the cold water. The remainder of the water is added and the mixture heated to form a paste, stirring the while. The other ingredients of the bait are then stirred in and the paste applied thinly on pieces of thin cardboard labelled "silverfish poison" and placed in cupboards, etc., frequented by the insects. (Reprint No. 312.)

Agricultural Chemistry

1. IMPROVEMENTS IN LABORATORY TECHNIQUE.

Since the inception of the Institute the methods in use in the chemical laboratories have been the subject of critical examination and revision. This has led to the selection or development of methods suitable for the routine examination of the wide range of soils encountered. Since the mineral composition of the plant is so closely associated with many fertility problems, methods for the determination of the inorganic constituents of plants have also been examined. These methods have now been brought together and published as a monograph. An important section of the work deals with the technique and the most suitable methods for the determination of the trace elements in plants.*

2. MINERAL DEFICIENCIES.

The chemical investigations into the effect of mineral deficiencies on the growth of plants have been in hand for some years, and they have further extended with special reference to the minor elements copper, zinc, and manganese, in addition to the investigations on molybdenum mentioned elsewhere in this report.

The determination of the amounts of copper, zinc, and manganese in Algerian oats when grown on a wide variety of South Australian soils has been completed, and the following range of values found for samples taken at the flowering stage:

Copper	0.7– 8.5 mg. per kg.	Mean 2.52 mg. per kg.
Zinc	4.1–28.9 mg. per kg.	Mean 12.55 mg. per kg.
Manganese	5–93 mg. per kg.	Mean 38.3 mg. per kg.

There was a significant correlation between the amounts of copper and zinc present in the 89 samples examined. Samples taken from areas known to be deficient in copper or manganese showed unduly low values for the element in question. The amounts of copper found in plants from deficient areas were always below 1 mg. per kg.

This survey was extended to determine the amounts of copper and zinc in a number of other plants growing on the Waite Institute soil. Leguminous plants were in general richer in both of these elements than the cereals and grasses. Two weeds showed unusually large amounts of both. Soursob (*Oxalis cernua*) contained 14 mg. of copper and 94 mg. of zinc per kg., while cape weed (*Cryptostemma calendulaceum*) had 21 mg. of copper and 120 mg. of zinc per kg.

An experiment was carried out to determine the effect of copper and manganese deficiencies on the development of the "take-all" fungus in wheat. Wheat plants, both inoculated and uninoculated with "take-all", were grown in nutrient solutions at various copper and manganese levels, but the fungus failed to maintain itself on the roots and the inoculated plants recovered after the initial set-back.

The distribution of copper between the leaf, stem and inflorescence of the wheat plant has been determined at seven different stages of growth. This was done in the course of an extensive pot experiment, wheat being grown on a copper-deficient soil in the absence of applied copper and in the presence of two different applications of copper. The largest proportion of copper was found in the young leaves. Absorption by the plant proceeded continuously until the flowering stage was reached. Only one-third of the total copper present in the plant was translocated to the grain at maturity.

* "Soil and Plant Analysis", by C. S. Piper, the University of Adelaide, 1942. A monograph from the Waite Agricultural Research Institute, pp. xiv + 368.

Deficiencies of copper, zinc, manganese, and boron have been produced in flax growing in nutrient solutions and the most characteristic symptoms, due to each of these deficiencies, observed. The application of this work to the study of a disease in flax is given in the section on Plant Pathology.

3. VIRUS INVESTIGATIONS.

The main object of these investigations is to increase our knowledge of the nature and properties of plant viruses. Two viruses with contrasting chemical behaviour are being studied, those associated with spotted wilt disease of tomatoes (tomato spotted wilt) and tobacco mosaic.

1. THE VIRUS OF TOMATO SPOTTED WILT.

(1) *Effect of Heat on the Virus.*

This virus is so readily inactivated by heat that temperatures which prevail in the laboratory during the summer and in liquids being centrifuged throughout the year are high enough to inactivate it. It was therefore essential to make careful determinations of the rate of inactivation at various temperatures in order to define safe limits within which to carry out operations designed to isolate the virus and to investigate certain of its properties. Previous records from this Institute were confined to the temperature at which the virus became inactive after a ten minute exposure (thermal death point) and referred to tests made without protecting the virus against inactivating influences of oxidizing agencies affecting the juice, and of unfavourable acidities. In the tests made during the period under review precautions were taken to avoid inactivation from these causes. Complete biological inactivation is considered to have taken place when the virus suspension will no longer infect plants onto which it is inoculated. The exact temperature at which the concentration of active virus is reduced below the minimum required to infect, varies with the initial concentration of virus and the susceptibility of the test plants. Under the conditions prevailing in these tests the thermal death point was found to be within half a degree of 46° C.

At 40° C. the virus was still active after 30 minutes but was non-infective after one hour, whereas the control suspension held at 20° C. had undergone no inactivation in this time. At 35° C. the rate of thermal inactivation was slow enough to be measured, and was found to follow a logarithmic course. After two hours' exposure, more than 99 per cent. of the virus had become inactive.

In preliminary tests in which whole plants growing in pots were exposed to an air temperature of 40° C. for five hours, the concentration of active virus was reduced to 5 per cent. of that in control plants maintained at 20° C.

(2) *Effect of Salicylate on the Virus (in vitro).*

The inactivating effect of solutions of potassium salicylate on the virus of tobacco mosaic has been previously discussed in these reports. Similar tests have been extended to the virus of tomato spotted wilt. It was found that tomato spotted wilt virus was inactivated even more readily by salicylate. As for tobacco mosaic virus, tests on tomato spotted wilt virus were carried out at 30° C. At salicylate concentrations of 0.1M and higher, inactivation took place in a matter of minutes. At a salicylate concentration of 0.04M the rate of inactivation followed a logarithmic course during the first two hours. Thereafter the concentration of active virus was reduced below the minimal infective concentration. At a concentration of 0.03M there was only slight inactivation. The temperature coefficient for this reaction is very high, the rate of inactivation being very much slower at 20° C. than at 30° C.

(3) *Attempts to Isolate the Virus.*

Preparatory work has been done towards obtaining the virus in a pure state. This has mainly consisted of observing the presence of the virus in the supernatant liquid and residue in various systems of centrifuging. Treatment of the infective juice with 25 per cent. ammonium sulphate solution precipitates the virus and enables a concentrate to be obtained. However, the temperatures developed in the liquids during centrifuging have presented difficulties because thermal inactivation supervenes at relatively low temperatures. Much time has been spent on attempts to minimize this difficulty.

(4) *Nitrogen and Phosphorus Metabolism of Virus-Affected Plants.*

Since plant viruses are essentially nucleoproteins it is of some importance to know what changes take place in the total and protein nitrogen and phosphorus in diseased and healthy plants. In the case of tomato spotted wilt it is likely that the sulphur metabolism will also be of some interest.

Accordingly two experiments were carried out in 1941, in which half of a batch of tomato plants was mechanically infected with tomato spotted wilt virus. At suitable intervals of time a number of infected and a corresponding number of healthy plants were withdrawn and harvested. Fresh and dry weights were determined, as well as total nitrogen and phosphorus. The separation of the protein fraction in the various samples is still going on, and these will be analysed in due course.

2. TOBACCO MOSAIC VIRUS.

(1) *Nitrogen and Phosphorus Metabolism of Virus-Affected Plants.*

A study similar to that described for tomato spotted wilt virus on tomato plants was made of the changes in the total and protein nitrogen and phosphorus during the course of mosaic disease in tobacco plants. Tobacco plants grown in sand cultures were artificially infected with ordinary tobacco mosaic virus and the leaves were harvested along with those of controls at suitable time intervals thereafter. Two series were grown, one with the nitrogen supply at an optimal level and another with insufficient nitrogen for normal requirements (the plant and the virus thus competing for nitrogen). Each leaf was divided at harvesting into halves along the midrib. One set of halves was used for fresh and dry weight determinations, and subsequent determinations of total and protein nitrogen and phosphorus. The other halves were crushed and the virus in them was estimated to find the distribution ratio of nitrogen and phosphorus between virus protein and other leaf proteins. This work is still in progress.

4. PLANT ANALYSES.

Analytical work on plants relates mainly to the nature of the variation in the chemical composition of pastures and forage plants as determined by systems of management, botanical composition, and fertilizer treatment. Much of this work is done in close collaboration with other departments, and some of it has been laid aside so that greater attention could be given to work of greater national urgency. During the past year or two increasing interest has been taken in rubber-bearing plants.

The Division of Plant Industry of the Council for Scientific and Industrial Research is interested in the introduction of species of leguminous forage plants suitable for tropical conditions, and contact has been maintained with the Division's Plant Introduction Station near Rockhampton, Queensland, with particular reference to the value of the introduced fodder plant Stylo (*Stylosanthes guianensis*), harvested at intervals in June, July, and August. The samples were examined for

nitrogen, phosphorus, and the proximate constituents: ash, protein, fibre, and nitrogen-free extractives.

As compared with the standard pasture plants from South Australia, such as subterranean clover and Wimmera rye-grass, Stylo is disappointing. The nitrogen content is low, ranging from 2.26 to 1.40 per cent. The values for soluble ash, 6-5 per cent., are also low. The values for fibre content are very high, 30 to 47 per cent., as contrasted with 23 per cent. for subterranean clover and 29 per cent. for Wimmera rye-grass at the flowering stage. On the other hand the phosphorus content for Stylo, varying from 0.39 to 0.21 per cent., is more nearly of the same order as is observed with the standard pasture species.

An investigation has also been made of the yield and composition of the oil distilled from the wormseed plant (*Chenopodium ambrosioides*) grown near Adelaide and at Sydney. The results showed promise of satisfactory yields of oil being obtained from Australian-grown plants with contents of the essential principle ascaridole falling well within the limits required by the British Pharmacopoeia. In some other respects, however, the oils varied from the recognized standards.

For some months investigations have been carried out as mentioned above on the rubber content of various species of plants grown in South Australia. Numerous species from various parts of the State have been examined, many of them first being separated into leaves, stems, bark, and roots, each portion being analysed separately. The plants examined included two species of *Asclepias* (cotton bushes), various *Euphorbias*, including Poinsettia, and some exotic and cactus-like species. *Solidago*, *Sarcostemma*, various species of *Ficus*, *Morus*, *Cassytha*, *Cichorium*, *Taraxacum officinale*, and *Inula graveolens* were other species examined. Some plants were found to be very resinous, containing up to 24 per cent. of resin. The character of the resins found varied very considerably from soft, opaque, aromatic smelling oleo types (or balsams) to brittle, hard, transparent solids. None of the plants examined showed quantities of benzene extractable substances ("rubber") worthy of exploitation, the maximum found being approximately 3 per cent. In some cases the extracts were very rubber-like, while in others, even from the same plant species obtained from different localities, the material found was less rubber-like but suggestive of some compound with properties related to those of rubber. The extracts from certain plants were in some cases wax-like rather than rubber-like. The plants examined were only taken at one growth stage, and results suggested that possibly systematic examination of the plant at different growth stages and under varying cultural conditions might be of value. At present this was impracticable, and no plants of suitable size and quick growing habits which contained useful quantities of rubber were found. The search for such desirable species was abandoned in favour of the examination of the recently introduced plants *Parthenium argentatum* (guayule) and *Taraxacum kok-saghyz* (the Russian dandelion), both of which plants were being developed in other parts of the world on account of their high rubber content.

By arrangement with the Council for Scientific and Industrial Research the systematic examination of both of these plants is being carried out at successive growth stages and under various cultural conditions in widely-dispersed plots and areas. The results so far observed may be briefly indicated. With plants six months old the highest amount of benzene-extracted material ("rubber") in guayule has not exceeded 1 per cent., but this is a slow-growing perennial plant and it is not expected that very appreciable amounts of rubber will be deposited in its tissues at such an early growth stage. The dandelion, however, which is a smaller plant, but a more rapid growing biennial, has produced in many cases 4-5 per cent. rubber in its large tap root, and several samples contained 6-7 per cent.; in two cases 9 per cent. was found. These later results are very encouraging, and the investigations are proceeding in co-operation with the Department of Agriculture.

Bacteriology

The use of the film-forming yeasts known as sherry "flor" for improving the quality of Australian sherry has been the subject of further investigation. Twenty-one strains of "flor" yeasts, some of reputed Spanish origin, have been isolated, but only some of these have the film-forming character sufficiently developed and are sufficiently tolerant towards alcohol to grow vigorously on wines. These yeasts bring about a normal alcoholic fermentation in grape juice, but they grow as films on the surface of wines left exposed to the air. Rapid and complete film development occurs only in the presence of a liberal supply of free oxygen. The optimum temperature for film formation on wine is in the vicinity of 20° C., and high temperatures seem to be largely responsible for the difficulties experienced in some wineries in maintaining films on wines during the summer months. Film formation is stimulated by small amounts of sugar—0.05 to 0.1 per cent.—but is inhibited by higher concentrations. The cultural history of the yeast used for inoculating the wine also affects the rate of film development.

It has been found that vigorous growth of the "flor," or yeast film, does not always impart to a wine the desirable flavour and aroma referred to as "flor" character. Unsatisfactory results may be due to the strain of "flor" used, the conditions under which it is grown, or the composition of the basal wine. Laboratory trials have indicated appreciable differences in the degree of "flor" character imparted to wines by different strains, and further strain tests are now being conducted in wineries.

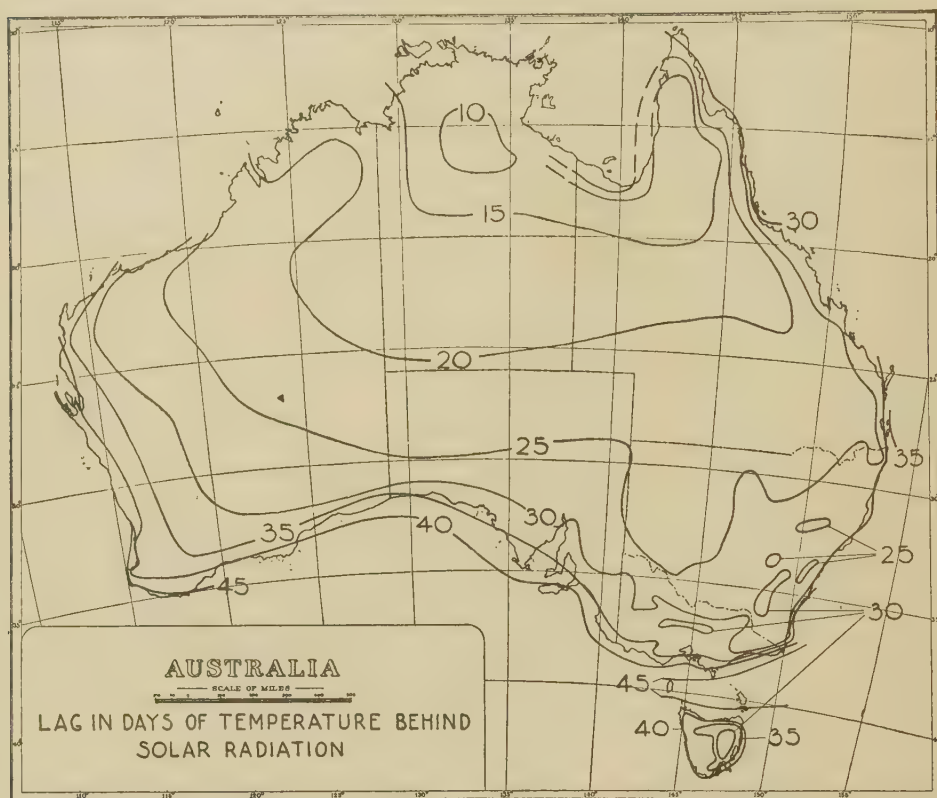
The metabolism of the organism on wine and on artificial media is being studied, and it appears that the chief energy source of the film when growing on wine is the oxidation of ethyl alcohol via acetaldehyde to CO₂ and water. As a result of the activity of the film, acetaldehyde accumulates in the wine, and the extent to which this occurs appears to be closely related to the development of "flor" character as estimated by experienced wine-tasters. Other changes which occur in wines as a result of "flor" development include reduction in fixed acidity, changes in volatile acidity, increase in total volatile esters and the formation of acetyl methyl carbinol. The effects of various factors on aldehyde accumulation and on other changes occurring in the wine are being studied.

Climatology

In the study of the geographical distribution of plants, animals, and soils, and in the determination of national agricultural policy, a knowledge of climatic conditions is of fundamental importance. The factors which are of greatest significance are the amount, distribution, and reliability of the rainfall and the temperature and humidity. The rate of evaporation has been found to be an important factor determining the efficiency of the rainfall and the water requirements of plants.

Since 1940 there has been in hand a detailed investigation of the trend in the yield of wheat and the relationship between yield and seasonal rainfall for the wheat areas of South Australia. It is expected that the work will be completed shortly. The trends upwards or downwards will give a measure of the efficiency of farming practices and will reveal any tendencies towards conservation or exploitation in the several parts of the State.

The choice of a system of agriculture in any region is primarily dependent on the rainfall-evaporation relationships throughout the year. The choice of particular species of plants and their varieties depends on temperature conditions as well. In Australia, among the cereals, wheat, oats, barley, and rye are suited to the winter conditions in the south generally, but maize and the grain sorghums demand summer temperatures. The sorghums are more adaptable to drought than is maize and are generally more suited to the Australian tropics.



The spread of a particular weed or of an insect pest relates also as much to temperature as to moisture conditions. The monthly march of temperature through the year has proved capable of useful study by the methods of Fourier analysis, and the twelve-monthly values can be reduced for practical purposes to the three values for annual mean, amplitude, and phase. The amplitude is approximately half the range between summer and winter temperatures and phase is best expressed in terms of the temperature lag behind solar radiation. These values have been calculated for Australian stations and the phase map is given in the accompanying figure. The south-west of Australia, in spite of its relatively short wet season, possesses advantages of rainfall reliability, late temperature phase, and low temperature amplitude which may give it special advantages in the production of special quality crops such as flax and tobacco.

The combination of mean, phase, and amplitude has been found useful in the search for Australian temperature regimes having parallels with those of selected localities in other parts of the world.

The Division of Soils

The headquarters of the Soils Division of the Council for Scientific and Industrial Research are at the Waite Institute. The interests of the Division are Commonwealth-wide and work has been done in past years in all the States of Australia. When the Division began its work in 1929, there already existed in the several State Departments of Chemistry and Agriculture analytical and advisory services to deal with soil fertility problems, and so far as possible co-operative projects with the State services were arranged. It had been obvious for some time and stressed by the Australian National Research Council that soil surveys and investigations should have preceded the land development schemes associated with repatriation, migration, and closer settlement. The main objective of the Division, therefore, became the systematic survey of the soils of certain selected areas, involving the mapping and study of the soils in relation to their agricultural, pastoral, or silvicultural use and at the same time a study of the distribution in Australia of the major soil zones and a recognition of such of the great soil groups of the world as were to be found in Australia. From the outset the description of soils was based on the soil "profile," that is, the characteristics of the soil throughout its depth to the parent material. This method was the outcome of many years of scientific work by the Russian school of pedologists and had become recognized by the United States Soil Survey as affording adequate criteria by the year 1921.

Early in the course of the soil surveys the co-operation of the Royal Australian Air Force was enlisted in the securing of aerial photographic surveys of the areas concerned; such aerial surveys are now regarded as affording the ideal working plans on which the field data of the soil surveyors are to be recorded.

In actual practice over the years the work of the Division has become advisory to the State Departments of Lands, Agriculture, or Irrigation with respect to their activities in land development and rural settlement.

The immediate effect of the war has been to restrict field activities primarily through the restriction on aerial photographic survey for other than military purposes. Some surveys are however regarded by the State authorities concerned as being of immediate importance, and endeavours are being made to readjust the scale of working to meet the altered conditions. The Ministry of Reconstruction is also concerned that all new potential schemes of reconstruction involving land development should receive early consideration, and the Division has undertaken to assess the nature of the scientific investigations required in all the cases submitted to the Ministry's Rural Reconstruction Commission.

A second effect of the war has been to bring the Division into contact with the engineers, both military and civil, Allied and Australian, concerned with the construction of runways on airfields. Divisional officers have undertaken surveys and carried out field and laboratory tests in soil mechanics and soil stabilization of importance in this connection. The Division is responsible for co-ordinating and developing the scientific side of soil-cement stabilization by arrangement with the Australian Portland Cement Association.

The association of the Division with civil engineers, the U.S. Corps of Engineers, and the scientific liaison section of the R.A.A.F. has been a most cordial one.

1. SOIL SURVEYS.

During 1941 and 1942 important surveys were completed or carried to the stage permitted by national emergency conditions in the Wakool Irrigation District of New South Wales and in County Victoria in South Australia. The Wakool dis-

trict is available for the intensification of pastoral production by means of irrigated pastures. It has provided a valuable auxiliary area for the growing of rice. In County Victoria the problems are associated with soil erosion caused primarily by the too exclusive employment of the two-course wheat-fallow rotation. In this county one area, the Hundred of Belalie, has received special attention by a team of workers including the State soil conservator, a research officer of the School of Economics of the University of Adelaide, and officers of the Soils Division. Assessments of farming practices, trends in wheat yield, and financial position of the farmers have been made on the one hand, and on the other hand detailed information has been collected on the physical factors concerned such as climatology, hydrology, topography, and stratigraphy. These factors can be directly related to the findings of the soil and erosion surveys.

The Deniboota Irrigation District, which adjoins the Wakool district in New South Wales, has been made the subject of a broad reconnaissance and it is proposed to continue such broad-scale surveys eastwards to include the important Berriquin district. The soils of these districts have relationships with those of the Murrumbidgee Irrigation Areas to the north and the Victorian districts across the River Murray to the south. When completed these surveys will together provide a comprehensive picture of the soils of the Riverina.

In Victoria an additional 25 square miles of potential irrigation country was surveyed in County Moira.

In South Australia, apart from the survey of County Victoria, a number of special surveys have been carried out on behalf of the Lands Department. The South-Eastern Drainage Board and the Land Board of South Australia have undertaken the reclamation of a peat swamp near Port MacDonnell, known as the Eight Mile Creek Swamp. Associated ecological investigations and the soil survey revealed a close parallel with the English fens. The reclaimed swamp gives every promise of being a highly productive area suitable for intensive settlement. There is some evidence, however, that, as is frequently the case with reclaimed swamp land, deficiencies in some of the minor elements will have to be overcome.

A survey has been carried out of 2,000 acres adjoining the old settlement at Renmark, only a proportion of which could be recommended for development.

In 1941, the Lands Department requested an examination of the irrigation possibilities of land on a low pumping lift in the Murray valley. A general survey has been made of the whole valley in South Australia. The principal conclusions are (1) that there is no large area suitable for irrigation development by Government enterprise either for horticultural or grazing uses, (2) that investigation is required of the possibility of developing at low cost the large areas of low level flats of heavy soils subject to periodic inundation from the river, and (3) that individual landholders could possibly make better use of river frontages, but that no clear advice can be given until experimental work has been undertaken.

The high level country fringing the Murray valley from the State border to Blanchetown has also been inspected. Much of the land in this region is unsuitable as it is in parts stony and shallow, whereas in others the lift is too high or the areas are too distant from the river. Three areas have proved worthy of further investigation, one above Renmark of 10,000 acres, one near Loxton of 11,000 acres, and a third near Lake Bonney of 3,000 acres. The area near Loxton has been the subject of the most detailed investigation. In the vicinity of Lake Albert and Lake Alexandrina at the mouth of the river, a number of small areas have also been examined.

A similar exploration of the Darling valley is of interest to the Irrigation Commissioners of New South Wales and such an investigation is under consideration as a future project for the Division.

During the two years under review the following were the main areas to be surveyed.

New South Wales:

Wakool Irrigation District, 640 square miles. Completing an area of 840 square miles.

Deniboota Irrigation District, 475 square miles of general reconnaissance.

Victoria:

County Moira, 25 square miles, completing an area of 355 square miles.

South Australia:

County Victoria, 625 square miles.

Eight Mile Creek Swamp, 4,000 acres.

Loveday Division, Cobdogla irrigation area, a reconnaissance of 5,000 acres.

Loxton, 11,400 acres.

During 1941, revised large scale soil maps were issued dealing respectively with Tasmania and tropical Australia and illustrating the distribution of the major soil zones.

2. SOIL MECHANICS.

Soil physics has been increasing in importance as a branch of the Division's work of recent years. The close association of the Division with the irrigation research stations at Merbein and Griffith and with the activities of the State irrigation authorities has led to investigations on problems of reclamation and drainage of waterlogged areas, particularly in the South Australian settlements. The field for study is a very extensive one and is far from being fully developed. Officers of the Division have undertaken surveys and testing in connection with the construction of runways on aerodromes in several parts of Australia and have been in a position to arrange for the services of State officers experienced in soil work to be made available on a number of occasions.

Of special interest has been the investigation of the suitability of local soils for soil-cement construction which has been a feature of some types of highway and runway construction in the United States. The Division undertook preliminary studies required in preparation for the first major soil-cement project in Australia. Assistance was given in site selection, soil survey of the area, and in the testing to determine the water, cement, and compaction requirements. Officers also assisted in the testing during constructional operations in three major projects. As a result of this experience a programme of research has been drawn up to elucidate problems that have arisen in field experience. The chief of these concerns the loss of density and ultimate strength which has been found to result from the inevitable delays occurring between the wetting and final rolling and compaction of the soil-cement mixture. It has been shown that such losses in density occur in soil-cement made from all but the sandiest soils.

It is proposed to continue with these investigations. Evidence is being accumulated on the relationship between soil types and their use in soil-cement construction, and correlations are being sought with American standards and experience.

3. SOIL CHEMISTRY.

The chemical activities of the Division are directed to the organizing of a testing and analytical service to meet the needs of the soil surveys and to the study of chemical problems of pedological and agricultural significance. In the first class come such matters of interest as the character of the colloidal material of the soil, both mineral and organic, the nature and quantity of the exchangeable ions held

by the soil, and the quantitative study of the distribution of the major constituents of the soil profile. Of agricultural significance are deficiencies or lack of availability in the known plant nutrients and the presence or absence of harmful constituents. A number of special agricultural problems of long standing, such as were known in the Cressy district in Tasmania and in the Mount Gambier district of South Australia, have been shown to be due to the inability of the crops concerned to obtain adequate amounts of major or minor elements. With development of country carrying sclerophyll forest or heath in the wetter parts of Australia, a new range of fertility problems has been met. Again, as a result of the researches of the Animal Nutrition Laboratory in Adelaide and of the veterinary workers in Western Australia many well recognized stock diseases such as coast disease in South Australia and an ataxia, known as "rickets" in Western Australia, have been recognized in recent years as being associated with soil deficiencies. These problems of mineral deficiency are known to be complicated by the availability as well as by actual deficiency of the element concerned and can only be completely investigated by taking into account the plant as well as the soil.

The elements now known to be of importance to plant or animal nutrition in Australia now include copper, manganese, zinc, cobalt, boron, and molybdenum as so-called "minor" elements, apart from the "major" elements phosphorus, nitrogen, and potassium, the value of which has long been recognized. It has become appropriate therefore to seek methods of soil examination which throw light on the many problems of deficiency or availability.

The spectograph has proved a valuable instrument in the study of these problems, particularly for the examination of the ash constituents of plants. It has been used in these laboratories for the examination of the minor constituents of ironstone gravels common to some parts of Australia, and it has been shown that molybdenum is one of the elements concentrated along with the iron in such gravels. The spectrograph was also used to estimate the amounts of molybdenum taken up by plants from the Tasmanian soil, the Cressy shaly clay loam, limed to varying degrees. The assessment of the availability of copper in the soil can as yet only be solved by the use of indicator plants. Mulder's biological method of using the spore colour of the fungus *Aspergillus niger* as indicative of the sufficiency or deficiency of available copper in a nutrient medium has been shown to be effective when soils are used as a source of copper in the medium. The method needs, however, a considerable degree of skill in its application and has not yet been tested under routine conditions for general advisory work.

The effect of liming the soil on the availability of plant nutrients is becoming of some interest. It has been recognized for some time that liming decreases the availability of manganese in certain soils, while in others the availability of phosphate is increased. The fixation of phosphate by the soil is of some practical interest in many parts of Australia, and the explanation given is in terms of anion exchange, phosphate being replaced by hydroxide on liming. It now appears also likely that molybdate takes part in a similar exchange reaction. It is desirable that methods be developed of determining anion exchange capacity which are as efficient and instructive as those now used for the evaluation of cation exchange. Some progress is being made in this direction.

4. SOIL BACTERIOLOGY.

The main interests of the Division of Soils in the field of microbiology relate to the study of the nodule organisms of leguminous plants. Endeavours are being made to isolate and maintain cultures of all the strains of *Rhizobium* likely to be of value in the inoculation of leguminous plants of both tropical and temperate regions. This involves the testing each year of the efficiency of the strains under

glasshouse conditions. There is a continued demand by farmers for cultures, and the practice is now widespread in the agricultural areas of South Australia. There is also a demand for cultures in the other States, a demand which is usually met by the biological services of the State Department of Agriculture concerned. Exchanges of cultures are maintained with these State Departments.

There is still considerable scope for study in the purely practical field of the preparation of commercial cultures, notably in the preparation of dried cultures of long viability. The temperature requirements of the several strains are being studied qualitatively, and it has been confirmed that the optimum temperature for the multiplication of *Rhizobium meliloti* and *R. trifolii* is in the vicinity of 37° C. and 29° C. respectively, being higher than was formerly supposed.

A problem of some general interest is the nature of the beneficial effect to a grass of a legume growing in association with it. This has received previous consideration in these laboratories and no direct benefit could be observed. In a new series of experiments of longer duration the legume has been clipped to within an inch or so of the surface of the soil. This leads to the loss of some of the nodules from the crown of the plant, but this loss of nodules has not been observed so far to lead to an improvement in the growth of the associated grass. In actual farming practice much of the beneficial effect of growing leguminous plants appears to be associated with the return to the soil of the whole plant in the process of green manuring or through the excretions of animals grazed thereon.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at three centres: at the Waite Institute itself, at Pallamana in the Murray Mallee (north-west of Murray Bridge), and at Yudnapinna (north-west of Port Augusta). In these two latter centres the observations are associated with the work on pasture regeneration in the more arid regions under the terms of the Ranson Mortlock Trust.

At the Waite Institute readings are taken at 9 a.m. daily, and include maximum and minimum temperatures, wet and dry bulb temperatures, maximum black bulb solar temperature, rainfall, evaporation, wind mileage, and barometric pressure. In addition, self-recording instruments deal with wind direction and velocity, and with soil temperatures at depths of one inch, six inches, twelve inches, and twenty-four inches.

Since the beginning of 1938 a self-recording rain gauge has been in operation.

Evaporation is measured from the free water surface of an open tank, 36 inches in diameter and 36 inches deep, with a surrounding guard-ring six inches wide. The mean monthly values for rainfall, evaporation, and air temperatures for the two years 1941 and 1942 are given below, the individual records for the years 1925-40 having been presented in previous reports.

Monthly Rainfall and Evaporation in Inches for the years 1491-42, Waite Institute.

Month.	Rainfall.		Evaporation.	
	1941.	1942.	1941.	1942.
January	3.63	1.79	7.95	8.15
February	.72	.23	6.39	6.58
March	1.65	.44	4.65	6.98
April	1.37	2.07	4.68	3.76
May	1.17	5.85	2.55	2.05
June	1.97	5.35	1.74	1.51
July	5.11	3.18	1.78	1.35
August	2.08	4.62	2.23	1.83
September	4.86	4.23	2.67	3.02
October	1.62	1.82	4.42	5.03
November	1.03	1.40	5.72	5.83
December	.93	.65	8.14	8.03
Total	26.14	31.63	52.92	54.12

Mean Monthly Air Temperatures for the Years 1941-42, Waite Institute.

Month.	Solar max.	Screen max.	Screen min.	Solar max.	Screen max.	Screen min.
	1941. °F.	1941. °F.	1941. °F.	1942. °F.	1942. °F.	1942. °F.
January	140.2	78.0	58.4	131.7	82.4	60.5
February	140.3	78.1	59.7	128.2	79.7	59.2
March	131.2	73.9	56.8	127.6	80.2	61.1
April	128.9	75.7	60.1	116.5	72.3	54.7
May	112.6	64.0	50.1	97.7	63.7	53.0
June	108.1	59.6	48.4	94.3	58.6	47.7
July	105.2	58.1	47.3	93.7	56.6	44.7
August	113.9	60.5	46.1	99.7	60.1	46.3
September	112.1	62.7	48.4	107.7	64.0	48.3
October	123.6	65.7	47.8	120.2	70.7	51.9
November	132.7	77.3	55.5	122.6	74.6	53.7
December	135.8	82.2	61.5	129.9	82.3	59.5
Mean	123.7	69.7	53.3	114.2	70.4	53.4

SOIL TEMPERATURES.

Temperatures in soil in bare fallow are recorded continuously by means of mercury in steel self-recording thermographs.

The mean monthly maximum and minimum soil temperatures for eighteen years are summarized in the following table:

Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches, and 24 inches for Eighteen Years, 1925-42, Waite Institute.

Month.	At 1".		At 6".		At 12".		At 24".	
	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.
January	109.8	63.9	85.5	71.8	77.9	72.6	74.0	71.2
February	106.8	63.7	84.5	71.3	77.3	72.3	74.5	71.9
March	100.8	61.8	80.3	68.8	74.7	70.1	73.0	70.4
April	83.6	55.4	69.8	61.1	67.1	63.5	67.6	65.0
May	70.8	50.5	61.2	54.7	60.2	57.4	61.7	59.7
June	63.2	46.8	55.5	50.4	55.0	52.6	56.5	54.9
July	61.4	45.9	53.8	49.0	53.2	50.8	54.3	52.8
August	65.2	46.7	56.2	50.3	54.3	51.6	54.6	52.8
September	73.3	49.7	61.8	53.9	58.4	55.0	57.6	55.5
October	84.9	54.3	69.9	59.3	64.4	60.1	62.3	59.9
November	97.0	59.2	77.9	65.0	70.6	65.7	67.4	64.8
December	106.5	62.7	83.4	69.6	75.4	70.2	71.6	69.0
Mean	85.3	55.0	70.0	60.4	65.7	61.8	64.6	62.3

NUMBER OF HOURS OF BRIGHT SUNSHINE.

The number of hours of bright sunshine is recorded daily by means of a Campbell-Stokes sunshine recorder, and is summarized in the following table:

Mean Number of Hours of Bright Sunshine per Month and per Day for Eighteen Years, 1925-42, Waite Institute.

Month.	Number of hours per day.	Number of hours per month.
January	8.8	272
February	8.6	244
March	7.5	232
April	5.6	168
May	4.2	131
June	3.3	99
July	3.2	100
August	4.4	138
September	5.6	170
October	6.7	210
November	8.0	240
December	8.4	260
Mean	6.2	Total 2,264

WIND VELOCITY.

The wind velocity is recorded at the Waite Institute in two ways, one by an anemo-biograph recording the wind velocity and direction at 30 feet, and by means of a three cup anemometer at eight feet above the ground.

*Wind Velocity at Eight Feet from the Ground from Cup Anemometer for Years 1938-42.
(Miles per month).*

Month.	1938.	1939.	1940.	1941.	1942.	Mean.
January	3,625	3,764	3,191	2,744	3,422	3,349.2
February	3,223	2,892	2,090	1,825	3,618	2,729.6
March	2,839	3,323	2,523	1,930	3,213	2,765.6
April	2,980	2,767	2,006	2,327	2,816	2,579.2
May	2,191	1,976	1,812	2,309	2,912	2,240.0
June	2,425	2,427	1,450	2,469	3,074	2,369.0
July	2,242	2,370	1,933	3,253	2,800	2,519.6
August	2,970	3,152	2,163	2,381	3,542	2,841.6
September	2,976	2,976	2,081	3,652	3,536	3,044.2
October	3,191	2,962	2,311	3,120	3,231	2,963.0
November	3,380	3,311	2,451	2,605	2,859	2,921.2
December	3,189	3,221	2,520	3,237	3,630	3,159.4
Total	35,231	35,141	26,531	31,852	38,653	33,481.6

GENERAL CLIMATOLOGICAL DATA.

The most important data on which the studies of climatology are to be based involve rainfall, evaporation, temperature, relative humidity, and atmospheric saturation deficit.

Evaporation from a free water surface is mainly dependent on saturation deficit and solar radiation. Evaporation may be regarded as proportional to saturation deficit when comparisons made of two or more localities relate to the same month. The ratios of rainfall to evaporation or of rainfall to saturation deficit have been found of special value in agroclimatological and bioclimatological studies.

The essential data for the Waite Institute, based on the mean values for the eighteen years 1925-42 are given in the following tables:

Month.	Rainfall. inches.	Evaporation. inches.	Temperature.			Relative humidity. per cent.	Absolute humidity gms. per cubic meter.
			Max. °F.	Min. °F.	Mean. °F.		
January	1.09	8.73	81.0	60.1	70.5	51	7.43
February	.99	7.11	81.1	60.6	70.9	53	7.68
March	.94	6.57	78.8	60.0	69.6	52	7.15
April	2.05	4.11	70.7	54.7	62.7	62	6.81
May	3.03	2.82	64.3	50.8	57.6	68	6.27
June	3.08	1.80	58.7	46.6	52.6	75	5.78
July	3.14	1.79	57.3	45.5	51.4	76	5.53
August	3.23	2.34	59.2	45.9	52.5	71	5.47
September	2.82	3.25	63.6	48.2	55.9	66	5.87
October	1.66	4.81	68.7	50.9	59.8	60	6.21
November	1.32	6.39	74.5	55.0	64.8	55	6.77
December	1.03	8.02	78.9	57.9	68.4	52	7.11
Total	24.38	57.74	Mean 69.7	53.0	61.4	62	6.51

Month.	Vapour Pressure. Inches of mercury.	Saturation Deficit. Inches of mercury.	Ratio of Rainfall to Evaporation.	Ratio of Rainfall to Saturation Deficit.
January	0.38	0.37	0.125	2.9
February	0.40	0.36	0.139	2.7
March	0.38	0.36	0.143	2.6
April	0.36	0.22	0.499	9.3
May	0.34	0.15	1.073	20.1
June	0.31	0.10	1.710	30.8
July	0.29	0.09	1.752	34.9
August	0.28	0.12	1.380	27.0
September	0.30	0.15	0.869	18.8
October	0.31	0.21	0.346	7.9
November	0.34	0.28	0.206	4.7
December	0.36	0.34	0.128	3.0
Annual	0.34	0.21	0.422	—

In the course of investigations the monthly values of the ratios of rainfall to evaporation have proved to be most instructive. With a ratio of 1, rainfall and evaporation as measured from a free water surface are, of course, equal. A value for this ratio of 0.5 has been found to be useful in bioclimatic studies, while for agroclimatic studies ratios of 0.33 to 0.25 have been found to indicate the lower useful limit of monthly rainfall.

The mean monthly values for these ratios are given above. The following table gives the length of the season during which the above-mentioned ratios are maintained. The agricultural season may be assumed to be determined by the period during which the ratio of rainfall to evaporation exceeds 0.33.

*Length of Season in Months during which certain Ratios of Rainfall to Evaporation are Exceeded,
Waite Institute.*

	R/E.	R/E.	R/E.	R/E.
Ratio	1.00	0.50	0.33	0.25
Length of period (months)	3.9	5.8	6.5	7.5

OBSERVATIONS AT COUNTRY CENTRES.

(1) PALLAMANA.

Monthly Rainfall and Evaporation in Inches for Years 1941-42.

Month.	Rainfall.			Evaporation.		
	1941.	1942.	Mean 1938-42.	1941.	1942.	Mean 1938-42.
January	8.13	0.47	2.10	9.35	11.71	10.08
February	0.33	0.36	0.86	8.28	8.88	8.37
March	0.64	0.12	0.29	6.69	9.22	7.78
April	1.22	2.79	1.72	5.15	4.93	4.58
May	0.74	3.21	1.14	2.99	2.63	2.73
June	1.77	1.57	1.47	2.10	1.90	1.94
July	1.38	1.47	1.34	2.29	1.90	1.82
August	0.94	1.64	1.47	2.78	2.82	2.80
September	2.53	2.15	1.27	4.12	4.04	4.28
October	1.60	1.10	0.86	5.70	5.95	6.30
November	0.76	2.61	1.54	7.79	8.22	7.82
December	0.60	0.84	0.58	10.74	10.70	10.06
Total	20.64	18.33	14.64	67.98	72.90	68.56

Mean Monthly Air Temperatures and Relative Humidity for the Years 1941-42.

Month.	Air Temperatures.				Relative Humidity.			
	Max.	Min.	Max.	Min.	Mean 5 years.		Mean 5 years	
	1941.		1942.		1938-42.		1941.	1942.
	°F.	°F.	°F.	°F.	°F.	°F.	Per cent.	Per cent.
January	77.8	54.7	84.7	56.9	83.3	56.9	64	49
February	79.7	57.7	80.3	55.3	82.0	56.3	50	59
March	74.8	54.1	80.6	54.0	80.3	54.9	68	55
April	74.8	52.3	71.6	49.9	72.4	50.8	68	75
May	64.1	44.3	63.3	51.0	65.0	46.2	81	88
June	60.2	43.4	59.1	42.7	60.2	41.9	82	92
July	59.3	43.0	57.2	40.2	58.2	40.7	86	86
August	61.2	39.9	61.2	42.0	61.6	40.8	82	81
September	64.7	43.0	65.9	41.6	66.7	42.8	72	77
October	67.2	45.1	73.3	44.4	72.6	46.4	70	65
November	78.6	52.5	76.4	50.4	76.2	51.3	58	54
December	82.4	56.7	83.6	55.2	81.5	54.9	44	54
Mean	70.4	48.9	71.4	48.6	71.7	48.7	69	70

(2) YUDNAPINNA.

Monthly Rainfall and Evaporation in Inches for Years 1941-42.

Month.	Rainfall.		Evaporation.	
	1941.	1942.	1941.	1942.
January	2.74	0.21	11.98	16.53
February	0.03	0.21	11.68	14.30
March	1.63	0.06	7.78	14.65
April	0.13	1.22	7.90	8.52
May	0.11	1.80	5.50	4.33
June	0.48	1.55	2.73	2.19
July	0.92	1.10	3.57	2.16
August	0.26	1.78	4.66	3.48
September	0.35	0.50	7.44	5.57
October	1.27	0.08	9.36	8.76
November	0.31	0.95	12.31	11.06
December	0.05	0.74	14.78	13.72
Total	8.28	10.20	99.69	105.27

Mean Monthly Air Temperatures and Relative Humidity for the Years 1941-42.

Month.	Air Temperatures.				Relative Humidity.	
	Max.	Min.	Max.	Min.	Mean 5 years	
	1941.		1942.		1941.	1942.
	°F.	°F.	°F.	°F.	Per cent.	Per cent.
January	84.3	61.1	92.7	64.6	47	39
February	87.5	62.7	89.5	63.0	48	54
March	80.7	57.8	85.8	61.5	64	44
April	79.9	58.0	76.9	54.9	53	58
May	68.9	45.4	68.0	51.9	64	70
June	63.0	42.6	61.5	44.0	80	81
July	62.2	42.0	59.6	41.7	88	81
August	66.4	42.4	67.6	41.3	82	70
September	71.4	46.8	72.4	44.7	61	52
October	74.7	51.0	79.2	52.3	49	52
November	87.6	59.0	84.5	57.2	41	45
December	91.3	64.6	90.7	63.9	35	41
Mean	76.5	52.8	77.4	53.4	59	57

Papers Published by the Staff of the Waite Agricultural Research Institute 1941-1942

I. SOILS.

- A. M. Acock. "An Examination of Mulder's Rapid Biological Method for Estimating the Amount of Available Copper in Soils." Jour. C.S.I.R. 14: 288-300. 1941. (Reprint 340.)

Mulder's observation on the change in spore colour of *Aspergillus niger* when grown in media with variable content of valuable copper has been confirmed. Soil suitably diluted with copper-free medium is used as the source of copper so that the resultant spore colour can be used as an indicator of its availability. The availability of copper in soils apparently is the same for higher plants as *Aspergillus*. It has been shown from 46 known examples that the mould may be used to distinguish "sound" and "unsound" soils. Certain modifications from Mulder's original method are recommended, mainly in emphasizing the need for partial sterilization of the soil before adding to cultures.

- J. G. Baldwin and R. L. Crocker. "The Soils and Vegetation of Portion of Kangaroo Island, South Australia." Trans. Roy. Soc. Sth. Aust. 65: 263-75. 1941. (Reprint 334.)

This paper is an ecological study of six hundreds on Kangaroo Island, South Australia. The geology and climatic data are briefly summarized. The soils are discussed in six groups: lateritic soils, grey siliceous sands, brown soils associated with sedimentary rocks, solonetz soils, soils associated with dunes, and basaltic soils. Mechanical analyses and chemical data are presented in the characteristics of the soil groups.

The complex ecology of the Island has been clarified by definition of eleven associations correlated with the soil groups and climatic factors. The principal undershrub plant species are listed for the associations. A map is included showing approximate boundaries of the main vegetation types.

- R. L. Crocker. "Notes on the Geology and Physiography of South-East South Australia, with Reference to Late Climatic History." Trans. Roy. Soc. Sth. Aust. 65: 103-7. 1941. (Reprint 320.)

The paper discusses the physiography of the south-east of South Australia in regard to consolidated and unconsolidated dune formations. The former are seen as exposed remnants of a line pan formation of pedological origin from which the leached siliceous overburden has been removed by wind action in a period of intense aridity. The resorted siliceous sands exist in dune form at such centres as Mount Burr. The same principle of leaching with accumulation of a lime pan is evident also in the south of Kangaroo Island, where also re-sorted siliceous sands, leached of calcium carbonate, are found.

Evidence is discussed for the occurrence of two periods of volcanic activity in the South-East, the earlier associated with the Mount Burr region and the latter with Mount Gambier.

- R. L. Crocker and H. R. Skewes. "The Principal Soil and Vegetation Relationships on Yudnapinna Station, North-West South Australia." Trans. Roy. Soc. Sth. Aust. 65: 44-60. 1941. (Reprint 319.)

The paper records study on soils and vegetation of an area of 25 square miles as a key to the ecology of the Station and basis for regeneration and erosion experiments to be carried out on it. The geology, physiography, and climate are briefly described. The soils were classified into eight groups associated with typical vegetation associations. Considerable latitude exists in the groups as to texture, but in general topographic drainage and plant relationship the soils are well defined. The laboratory examination covers mechanical analyses and standard chemical determinations.

Five vegetation associations are defined conforming to three formations: shrub steppe, tree steppe, and scrub. The floristics are dealt with in detail with a full list of plant occurrences and comments on their habitat. The problem of vegetation degeneration and erosion is briefly outlined for the locality, and some information on pyric succession in the tree steppe formation is given.

- R. I. Herriott and E. J. Johnston. "A Soil Survey of the Waikerie Irrigation Area, South Australia." C.S.I.R. Bull. 141. 1941. (Reprint 333.)

The bulletin describes the results of a soil survey of about 6,000 acres of horticultural land at Waikerie, South Australia. The soils have been mapped as 15 types, and a group of miscellaneous stony soils. The bulk of the soils are types recognized in previous surveys in the Murray Valley, but four new types are named for the first time. The soils are frequently stony; 40 per cent. of the area has solid limestone in some degree in the profile. The field occurrence and character of the soils are fully described, and analytical data presented and discussed on their physical and chemical characters.

Stress has been laid on the relationship of soils to horticultural position in the settlement, e.g. zinc deficiency, leaf scorch in apricots, leaf drop in citrus. The available water status of the main soil types has been studied. Soil drainage, which is unique on the Murray River settlements, is discussed. Salinity problems are not serious. A soil map in colour is included.

- G. D. Hubble and R. L. Crocker. "A Soil Survey of the Red Cliffs Irrigation District, Victoria." C.S.I.R. Bull. 137. 1941. (Reprint 306.)

This bulletin covers an area of 12,000 acres adjacent to the Mildura Irrigation District in north-western Victoria. The area is a horticultural settlement of high productivity. The soils are predominantly light-textured, and similar types have been described from other areas on the Murray River. Twelve named soil series are described with one unnamed soil type. The relation between soil type, topography, and vegetation is discussed.

Laboratory analyses have been made on over 100 samples, covering the usual physical and chemical determinations. The soils are relatively free of soluble salts.

The settlement is served by an excellent irrigation and drainage scheme which has contributed towards the soundness of the community and prevented serious soil troubles arising, such as waterlogging. A soil map in colour is reproduced.

- T. J. Marshall. "Progress in Soil Physics." Jour. Aust. Inst. Agric. Sci. 8: 18-22. 1942. (Reprint 350.)

One of the most profitable fields for recent soil research has been the study of water in soils: its retention by them, and its movement. Advances in the understanding and measurement of soil structure have also been considerable. These and other points are discussed in a review of four books dealing with the physical properties of soils.

- T. J. Marshall and R. F. Williams. "Determination of the Permanent Wilting Percentage of Soils." Jour. Aust. Inst. Agric. Sci. 8: 109-11. 1942. (Reprint 359.)

Veihmeyer's method for the determination of permanent wilting percentage is described. It was found, at the conclusion of a number of wilting tests, that water had been withdrawn uniformly from different layers of the soil.

There is no constant ratio between the moisture equivalent and permanent wilting percentage of soils, and indirect methods for calculating the permanent wilting percentage by this means are invalid. The ratio varies between 1.4 and 3.3 for the soils used in these tests. The indirect method can be applied, with caution, only to local groups of soils for which the appropriate ratio has first been determined experimentally.

- J. A. Prescott and H. R. Skewes. "An Examination of Some Soils from Tropical Australia." Trans. Roy. Soc. Sth. Aust. 65: 123-39. 1941. (Reprint 322.)

Samples of soils collected in 19 localities in the Kimberleys, the Northern Territory, and North Queensland have been examined in the laboratory for mechanical analysis and chemical properties, and the results correlated with field observations made during three field traverses in these areas. A soil map of tropical Australia is presented in which the following zones are recognized: ranges and tablelands, desert sandhills, desert sand plain, brown soils of light texture, brown and grey soils of heavy texture, desert loams, rendzinas and black earths, red and red-brown soils, podsols, residual podsols, low country subject to periodical flooding, and tidal marshes and deltaic formations. The climatic factors associated with the characteristic soil-forming processes in tropical Australia are briefly discussed.

- C. G. Stephens. "The Soils of Tasmania." C.S.I.R. Bull. 139. 1941. (Reprint 318.)

This publication is a record of the known facts about Tasmanian soils up to 1939. The classification of the soils in relationship to the taxonomic scheme of Thorp and Baldwin is presented, and each of the zonal and intrazonal soils is discussed in relation to relevant features such as climate, geology, and vegetation. Finally the land-use and soil problems associated with each of the soils are stated and discussed. The soil map presented with this bulletin has the 500-foot and succeeding thousand-foot contours superimposed on it.

- C. G. Stephens, R. L. Crocker, B. E. Butler, and R. Smith. "A Soil and Land Use Survey of the Hundreds of Riddoch, Hindmarsh, Grey, Young and Nangwarry, County Grey, South Australia." C.S.I.R. Bull. 142. 1941. (Reprint 341.)

This survey, undertaken between 1937 and 1940, deals in lengthy detail with the soil types on an area of 500 square miles. The taxonomy and morphology of the soils is related to climate and parent material, there being present in the area both zonal and intrazonal soils, the former represented by a group of podsoils and the latter largely by calcimorphic soils, rendzinas and Terra rossa. The area surveyed is very largely used for forest and grazing purposes, the forestry being largely concerned with the exotic *Pinus radiata*. A land-use map (1940) of the area is presented and discussed.

II. AGRICULTURAL CHEMISTRY—LABORATORY TECHNIQUE.

- C. S. Piper and A. C. Oertel. "Silica and Pyrex Glass Stills with Automatic Constant-Pressure Feeds." Ind. & Eng. Chem. (Anal. Ed.), 13:191-2. 1941. (Reprint 313.)

A description of three stills which have been used for the continuous redistillation of water in order to secure a product suitable for investigations on the effect of small quantities of the heavy metals on plant growth. The stills have a capacity of 1-2 litres per hour. One type of still, with an electric immersion heater sealed into a pyrex glass flask, has a thermal efficiency of about 90 per cent.

- R. E. Shapter. "The Estimation of Alkalies in Plant Material." Aust. Chem. Inst. Jour. & Proc. 9:42-4. 1942. (Reprint 345.)

The unsatisfactory nature of aqueous ammonium carbonate as a reagent for quantitative removal of calcium and magnesium is generally known. Even in alcoholic solution it was found to be unreliable, and observations to this effect were recorded especially in the analysis of plant material. Details of technique worked out are given. An alternative method using ammonium oxalate and 8-hydroxyquinoline, which proved satisfactory, is outlined.

- A. Walkley. "The Extraction of Zinc from Ammonia Buffers by Means of Dithizone." Aust. Chem. Inst. Jour. & Proc. 9:29-34. 1942. (Reprint 344.)

An examination of the partition of zinc between aqueous ammonia buffers and chloroform solutions of dithizone for different pH values and for varying ammonia concentrations has been carried out.

The results show, firstly, that if allowance is made for the partition of dithizone itself between the two liquids, zinc may be readily extracted from the aqueous solution up to pH 10.5 at least; and secondly, that the partition of zinc is more closely related to the concentration of ammonia than to pH value. The results of the study have also pointed the way to a simplified analytical procedure enabling zinc to be extracted at pH 9.8 from digested plant material in the presence of suspended silicas.

- A. Walkley. "The Discharge of Zinc Ions at the Dropping Mercury Cathode. A Test of the Ilkovic Equation." Jour. Amer. Chem. Soc. 63:2278-9. 1941. (Reprint 346.)

The use of the polarograph for the determination of zinc in plant materials required an examination of the relation between the limiting current produced during the electrolysis of zinc solutions and the concentration of the latter. The relation was found to be linear, and the observed limiting currents agreed well with those calculated by means of the Ilkovic equation from the known characteristics of the dropping electrode.

- A. Walkley. "The Determination of Zinc in Plant Materials." *Aust. Jour. Exp. Biol. & Med. Sci.* 20: 139-47. 1942. (Reprint 357.)

A method is described for the determination of zinc on one-gram samples of plant material, using a wet ashing procedure, dithizone extraction and polarographic determination.

It is shown that sodium perchlorate can be used instead of perchloric acid for the wet ashing, and that the suspended silica which is always present causes no difficulties in the subsequent extraction with dithizone. The errors introduced by impure reagents and certain types of glassware are discussed. By simple methods of purification the blank may be reduced to a negligible amount. Recovery tests show that the precision and reproducibility of the method are of the order of ± 3 per cent.

Where temperature control is not possible, the internal-standard method may be used, cadmium serving as the standard of reference.

III. MINERAL DEFICIENCIES.

- A. J. Anderson. "Molybdenum Deficiency on a South Australian Ironstone Soil." *Jour. Aust. Inst. Agric. Sci.* 8: 73-5. 1942. (Reprint 353.)

Following observations that pasture improved where timber had been burned on ironstone soils in the Meadows district, experiments were conducted over a period of years to determine the factors concerned in the response.

An increase in the yield of lucerne from 1.60 to 3.13 gm. per pot, due to an application at the rate of 2 lb. per acre of sodium molybdate was followed by significant responses of subterranean clover to 1 lb. per acre of sodium molybdate.

- C. S. Piper. "Marsh Spot of Peas: A Manganese Deficiency Disease." *Jour. Agric. Sci.* 31: 448-53. 1941. (Reprint 338.)

By growing peas in water cultures with carefully regulated amounts of manganese, the effects of a deficiency of this element have been studied. Complete absence of manganese produces a mottling of the younger leaves, and death of the growing tip as reported in an earlier paper. The plant does not reach the flowering stage. Small amounts of manganese, insufficient for normal requirements, enable increased growth and seed formation. The seeds show marsh spot lesions, the severity of the lesions being greater at the lower manganese concentrations. Normal growth and sound seed are produced when sufficient manganese is present in the nutrient solution.

Marsh spot results from a partial deficiency of manganese, the amount available to the plant being sufficient for its normal vegetative requirements, but not for healthy seed production.

- C. S. Piper. "Investigations on Copper Deficiency in Plants." *Jour. Agric. Sci.* 32: 143-78. 1942. (Reprint 358.)

A water culture technique has been described which makes it possible to determine with precision the effects on plant growth resulting from the absence of traces of the various heavy metals.

The essential nature of copper for plant growth has been confirmed, and the quantitative data presented show that the addition of traces of copper to a nutrient solution leads to increases of growth of the order of 200 to 1,200 per cent.

The characteristic symptoms produced by growing oats, peas, wheat, Wimmera rye-grass, *Phalaris*, flax, tomato, subterranean clover, and lucerne in nutrient solutions devoid of copper are described. Copper becomes necessary for normal healthy growth at an early seedling stage, and is required so long as active growth is proceeding. Optimum growth of oats was obtained throughout a wide range of copper concentration in the nutrient solution.

Oats grown in a copper-free nutrient solution until the development of acute deficiency symptoms, recovered and completed their normal life cycle on the addition of sufficient copper to the solution.

The copper content of oats at various stages of growth has been determined. The proportion of copper in the dry matter of the plant was greatest in the young stages and rapidly decreased as growth proceeded.

The copper content of mature oat plants showing symptoms of copper deficiency was less than 1.0 mg. per kg., whether grown in nutrient solution or obtained from copper-deficient soils. Oats which ceased growth from copper deficiency at an earlier stage of development contained a relatively greater amount of copper in their dry matter.

The degree of moisture saturation of the soil had little effect on the copper uptake of plants. An increase of soil acidity to pH 4.7 increased the availability somewhat, while partial sterilization by heat had a greater effect on availability. In neither case, however, was the increase of the same order of magnitude as the corresponding increase in the availability of manganese.

The increased absorption of copper by plants as the result of applications of copper sulphate to the soil was surprisingly small.

Rye has the power of absorbing more copper from a given soil than oats, and can grow normally to maturity on a soil on which oats fail from copper deficiency.

IV. VIRUS INVESTIGATIONS.

Barbara Cooke and R. J. Best. "The Inactivating Effect of Salicylate on Suspensions of Some Animal Viruses (herpes, infectious myxoma, Shope fibroma, vaccinia poliomyelitis.)" *Aust. Jour. Exp. Biol. & Med. Sci.* 19: 93-9. 1941. (Reprint 315.)

The viruses of herpes, Shope fibroma, vaccinia, and infectious myxoma undergo rapid inactivation when brought into contact with solutions of potassium salicylate of pH 7 at 22° C. In all cases more than 99 per cent. of the virus was rapidly inactivated at salicylate concentrations between 0.10M and 0.02M.

Poliomyelitis virus was not tested for partial inactivation, but complete inactivation was not brought about by concentrations as high as 1.2M. At lower concentrations some anomalous results were obtained.

The rate of inactivation was determined for Shope fibroma virus, and was found to be logarithmic. Complete inactivation can, therefore, be attained only after infinite time, and a distinction is drawn between complete mathematical and complete biological inactivation. Herpes virus was rendered non-infective by 24 hours' contact with 0.15M salicylate at 22° C., and pH 7 when dialysed before inoculation, irrespective of whether the infectivity tests were carried out in rabbits or in mice. On account of the small residuum of active virus, the limiting concentrations of salicylate necessary to render the other three viruses non-infective in 24 hours are not so well defined, and are much higher. These, the influence of dialysis on the "end point", and a comparison with tobacco mosaic virus are discussed in the light of data presented.

Salicylate-treated virus myxomatosis was not an effective immunizing agent.

V. PLANT NUTRITION AND PLANT PHYSIOLOGY.

E. A. Hanson. "A Note on the Metabolism of Chloroplast Protein." *Aust. Jour. Exp. Biol. & Med. Sci.* 19: 157-9. 1941. (Reprint 316.)

A method is described for the separation of chloroplasts from other cell constituents by centrifugation. Using *Phalaris tuberosa* it was found that the protein of the chloroplasts represented approximately 36 per cent. of the total leaf protein. Factors governing the protein-chlorophyll ratio of the chloroplasts are investigated, and the data suggest that surplus (storage) protein is produced in the latter when the nitrogen supply is abundant.

A. H. K. Petrie. "The Intake of Ions by Carrot Tissue at Different Hydrogen-Ion Concentrations." *New Phytol.* 37: 211-31. 1938. (Reprint 339.)

Preliminary observations on the relation of ion intake by carrot tissue to the pH of the medium show that for cations the relation is complex, and changes with time. Soon after immersion, and again after the lapse of some days, however, it has the form expected in a Donnan system. With anions the relationship is, in general, as expected, but other factors may play an important part.

A. H. K. Petrie. "Mineral Nutrition of Plants." *Ann. Rev. Biochem.* 11: 595-614. 1942. (Reprint 368.)

This review covers the more important current contributions to the subject. The author stresses the need for defining and applying the fundamental principles involved in metabolism and growth to all investigations on mineral nutrition of plants.

- N. S. Tiver. "Studies of the Flax Plant. 1. Physiology of Growth, Stem Anatomy and Fibre Development in Fibre Flax." Aust. Jour. Exp. Biol. & Med. Sci. 20: 149-60. 1942. (Reprint 356.)

The growth of flax was depressed by low moisture treatment applied after flowering, the effect being attributable to a depression of the net assimilation rate (protein basis).

Anatomical studies showed that the outer layer of cells in each bundle was the first to develop the characteristic thickening of the fibre cells. Normally this process takes place progressively towards the inner boundary of the fibre bundle, but with low moisture treatment, the inner cells fail to thicken. Lignification of fibre cells was depressed by low moisture treatment.

At maturity, low moisture treatment decreased the yield of fibre by 40 per cent., and the percentage weight of fibre in the straw was depressed by over 20 per cent.

- Joan Walkley and A. H. K. Petrie. "Studies on the Nitrogen Metabolism of Plants. IV. On the Changing Nature of the Relation between Proteins and Amino-Acids." Ann. Bot. n.s. 5: 661-73. 1941. (Reprint 352.)

In a single mature leaf of the barley plant, the amounts of proteins and amino-acids decline with age, so that the relation between these two variables forms a curve concave to the amino-acid axis. If an additional supply of nitrogen is given to the plants while this drift is in progress, the values of the two variables are restored to high magnitudes, but the subsequent decline in amino-acids sets in before that of the proteins. That the history of the leaf permanently affects the above relation is shown by certain differences in the curves for treated and untreated plants.

- J. G. Wood and A. H. K. Petrie. "Studies on the Nitrogen Metabolism of Plants. V. The Relation of Carbohydrate Content to Protein Synthesis in Leaves." Aust. Jour. Exp. Biol. & Med. Sci. 20: 249-56. 1942. (Reprint 363.)

An experiment is described wherein plants of *Phalaris tuberosa* L. were subjected to differential sucrose and nitrogen treatments in a constant environment. It is shown that protein content shows no relationship with carbohydrates as expected from a simple mass-law relationship, for all carbohydrates decrease in amount as protein content increases. Over 90 per cent. of the variance of protein is accounted for in terms of amino-acid and water contents, and the evidence indicates that proteins are synthesized from the whole of the amino-acids within the cell rather than along any alternative path.

VI. FIELD CROPS, PASTURES AND WEEDS.

- D. B. Adam and Joan Stokes. "The Association of *Rhizoctonia bataticola* with Retting Flax in South Australia." Proc. Linn. Soc. N.S.W. 67: 313-7. 1942. (Reprint 366.)

A fungus identified as *Rhizoctonia bataticola* on the basis of a study of its morphological, physiological, and pathological characters occurs on flax straw grown in South Australia. When it develops vigorously this fungus destroys the quality of fibre. Such a development occurred on flax straw maintained for experimental purposes at 90° F. but this temperature is very much higher than that occurring in the field during the period when "dew retting" can be practised. The fungus has been observed on straw spread in the field for dew retting, but under these conditions its development relative to other micro-organisms is very slight.

- C. M. Donald and D. L. Parker. "A Note on 'Perennial' Prairie Grass." Jour. Aust. Inst. Agric. Sci. 8: 29-30. 1942. (Reprint 348.)

Following a previous investigation of prairie grass (Reprint 274, Report 1939-40, p. 65) selected lines were compared in a replicated sward trial at the Waite Institute. "Perennial" prairie grass, a strain selected from material of unknown origin at the New England Experiment Farm, New South Wales, proved to be the most valuable of a wide range of material tested. This strain is vigorous, high-yielding, and immune from smut infection. It is suggested that the misnomer "perennial" prairie grass should be replaced by some such name as New England prairie grass.

- C. M. Donald and H. C. Trumble. "Palestine Strawberry Clover (*Trifolium fragiferum*, L.)." Jour. Aust. Inst. Agric. Sci. 7: 124-5. 1941. (Reprint 327.)

The history of the introduction of Palestine strawberry clover into Australia is recorded, and the results of agronomic investigations of the strain in South Australia summarized. Evidence is given for a high degree of vigour of the Palestine variety compared with standard commercial types. This strain was commercialized in 1938.

- D. L. Parker. "Strain Variation and Seed Production in Kikuyu Grass (*Pennisetum clandestinum* Hochst.)." Jour. Agric. Sth. Aust. 45: 55-9. 1941. (Reprint 324.)

The botanical features of *P. clandestinum* are described, and the introduction of this species into Australia discussed. Investigation of material from various sources, including the native habitat in Kenya, revealed considerable differences in growth form, capacity for seed production, and other agronomic features. It has been shown that seed-producing forms can be readily isolated in South Australia and that the propagation of these forms is likely to increase considerably the scope of usefulness of the grass in Australia.

- K. A. Pike. "Fibre Flax. Investigations at the Waite Institute." Jour. Agric. Sth. Aust. 44: 496-507. 1941. (Reprint 317.)

Results of investigations over the four years 1937-40 showed that flax straw of high commercial quality could be produced when the crop was sown on well-worked fallow.

From trials with the Liral Crown variety of fibre flax, it was found that the greatest effects on yield were produced by modification in time of sowing.

Yields of hand-pulled flax exceeding 2.5 ton per acre were obtained with early seeding in each of the four seasons.

Late sowings yielded about one-third less flax straw and seed than were produced from earlier sowings.

Seed production was more affected by season than straw production.

Increasing seed rates to a maximum of 80 lb. per acre produced higher yields of straw, and higher percentage of fibre in the straw, but a seeding rate of 40 lb. per acre gave the highest yield of seed for early sowing, whilst with late sowing, seed yields were not affected by rate of seeding.

The results suggest that 1 cwt. to 1½ cwt. of superphosphate per acre is the optimum fertilizer dressing. The application of higher dressings of super, and the use of sulphate of ammonia, gave slight improvements in yield but increased the tendency of the crop to lodge. Appendices briefly describe the rooting habit of flax, and a flax deseeding machine.

- C. A. N. Smith. "The Comparative Grazing Values of Top-Dressed Natural and Sown Pastures in the Middle South-East of South Australia." Jour. Agric. Sth. Aust. 45: 485-96. 1942. (Reprint 355.)

An experiment to compare the relative grazing values of top-dressed pastures of Wimmera rye-grass + subterranean clover, *Phalaris tuberosa* + subterranean clover, and top-dressed natural pastures was carried out over a period of five years at the Experiment Station, Kybybolite, in the middle south-east of South Australia.

The four areas of each pasture type were grazed rotationally by a standard flock of English Leicester-Merino comeback ewes and their lambs, together with additional sheep whenever considered necessary to utilize surplus herbage.

The sown pastures, which did not differ significantly from each other except in production of herbage, proved superior to the natural pasture in carrying capacity, fodder production, and botanical composition, live-weight gains of the ewes (which were particularly shown in their initial development), percentage lambing, and wool production per acre.

The possibility of obtaining better relative results from the sown pastures by more effective utilization through cutting for silage or hay, with subsequent feeding of this material, and by adopting a longer interval between grazings during the period of restricted growth is pointed out.

- C. A. N. Smith. "The Adaptability of 'Bacchus Marsh' Subterranean Clover to Certain Areas of South Australia." Jour. Agric. Sth. Aust. 45: 602-5. 1942. (Reprint 365.)

The "Bacchus Marsh" strain of subterranean clover has considerably surpassed the "Dwalganup" strain in production under sward conditions over two or more years at the Waite Institute, at Salisbury, and on the soils of the lateritic neoplain of Kangaroo

Island, and has proved of equal productivity to the Mount Barker strain over three years at the Waite Institute, and during the year of establishment on Kangaroo Island. On account of its eight to ten days' earlier flowering than the Mount Barker strain, it is thought that the Bacchus Marsh strain will prove of great value in the Clare, Bordertown, and Port Lincoln areas, in addition to those mentioned above, where the climatic conditions during the spring are too severe in some seasons for the successful seed-setting of the Mount Barker strain.

- H. C. Trumble. "Grassland Investigations at the Waite Agricultural Research Institute, University of Adelaide." Imp. Bur. Past. & For. Crops. Herb. Publ. Ser. Bull. 29: 57-60. 1940. (Reprint 323.)

An outline is given of investigations carried out from 1925 to 1940 in conjunction with the Council for Scientific and Industrial Research, the Empire Marketing Board, the Carnegie Corporation of New York, and the Australian Wool Board. The scope of the work has included the ecological zoning of pasture types, plant introduction, and the testing of herbage species, pasture plant breeding and selection, a study of pasture technique, natural regeneration and succession in pastures, pasture establishment, associated growth and competition, investigations of seed viability, fertilization, and management of pastures, effect of pastures on the grazing animal, chemical composition and transpiration of herbage plants.

- A. J. K. Walker and D. L. Parker. "Caltrop (*Tribulus terrestris* L.) and its Recent Spread in South Australia." Jour. Agric. Sth. Aust. 45: 109-12. 1941. (Reprint 329.)

Information is given concerning the botanical features, means of dispersal, economic importance and methods of control of the caltrop weed. The danger of its further spread in South Australia is stressed.

- D. C. Wark. "Addition of Hormones to Mercurial Fungicidal Dusts that Reduce Germination of Wheat." Jour. Aust. Inst. Agric. Sci. 7: 156-8. 1941. (Reprint 337.)

Two plant hormones— α naphthyl acetic acid and β indolyl acetic acid—were incorporated in a fungicidal dust containing 1.5 per cent. of mercury as ethyl mercury phosphate. They were shown to lessen the harmful effect of this dust on the germination of wheat, under both laboratory and field conditions. β indolyl acetic acid gave more consistent results than α naphthyl acetic acid, but neither hormone restored the germination to a value approaching that of undusted grain.

- D. C. Wark. "The Influence of Storage in Contact with Certain Seed-Pickling Dusts on the Germination of Grain." Jour. Aust. Inst. Agric. Sci. 8: 22-5. 1942. (Reprint 349.)

Seed grain of wheat and barley were dusted with a series of fungicidal dusts and stored in closed containers at a range of temperatures, and germinated in the field.

The germination of seed wheat was improved by the majority of dusts, but certain dusts, more especially those containing ethyl mercury phosphate, caused a depression of the germination of grain stored at or above twenty degrees centigrade. No injurious effect was observed on the germination of barley, although the dust most injurious to wheat was excluded from the barley trial.

- D. C. Wark. "Trends in the Yields of Fallow-Sown and Stubble-Sown Cereals in Some South Australian Experiments." Trans. Roy. Soc. Sth. Aust. 66: 133-41. 1942. (Reprint 362.)

The method of partial regression was employed to correct for rainfall the annual yields from single-plot rotation experiments at Booborowie Experiment Farm, Roseworthy Agricultural College, and the Waite Institute. The following trends in yield were observed.

At Roseworthy the yield of wheat declined at the rate of half a bushel per annum on land farmed under the wheat-fallow rotation. At Booborowie and the Waite Institute the yields of stubble-sown oats and barley declined at significant rates. The introduction of a year of natural pasture at Booborowie, or of a year of rye-grass at the Waite Institute decreased the rate at which the yield of oats on stubble declined.

The effect of dwindling phosphate supply was demonstrated at Booborowie, where the yields of wheat on fallow declined on land that had received no phosphate. The inclusion, at Booborowie, of a lucerne pasture for three years was associated with a decline in yield of wheat on fallow.

- K. Woodroffe. "Shrub Pastures under Low Rainfall. An Experiment on Grazing Management." Jour. Aust. Inst. Agric. Sci. 7:117-21. 1941. (Reprint 326.)

An experiment to determine the reaction of bluebush pasture to varying forms of controlled grazing is described and a number of associated problems discussed. The experiment covers $4\frac{1}{2}$ square miles of tree-shrub steppe, and involves 26 miles of fencing; it was designed to secure maximum practical information based on an essentially scientific approach. The methods employed to give a measure of forage production from shrub pasture are described.

VII. DISEASES OF PLANTS.

- D. B. Adam. "Potato Diseases in South Australia." Jour. Agric. Sth. Aust. 45:518-27. 1942. (Reprint 361.)

This is a popular account, with illustrations, of the more important diseases affecting potatoes grown in South Australia.

- T. T. Colquhoun. "Black Dot Root Rot of Tomatoes." Jour. Agric. Sth. Aust. 44:572-5. 1941. (Reprint 321.)

The results of two experiments with *Colletotrichum atramentarium* (B. & Br.) Taub., are set out. In one, under commercial glasshouse conditions, it was found that allowing the soil to remain in a roughly dug condition for two and a half months during the summer reduced the percentage of diseased plants below that on plants grown in soil which had been rototilled and left for the same period. This effect was independent of whether the cultivation was carried out in moist or dry soil.

In the other experiment, conducted in glazed earthenware pots, it was demonstrated that the fungus could remain viable for at least eleven months in both moist and dry soil in the absence of host plants.

- T. T. Colquhoun. "Spray Trial to Control Spotted Wilt of Tomatoes." Jour. Aust. Inst. Agric. Sci. 8:171-2. 1942. (Reprint 367.)

The object of this trial was to determine if the spread of tomato spotted wilt could be minimized by controlling the known vectors: *Thrips tabaci* and *Frankliniella insularis*. A bait consisting of sugar and tartar emetic was sprayed onto the tomato plants. The sprayed plots showed a significant reduction in the number of infected plants, but with 30 per cent. infection in these, it is doubtful if the method is commercially practicable.

VIII. ECONOMIC INSECTS.

- H. G. Andrewartha. "Some Laboratory Tests with Oil Emulsions against Wheat Weevil, *Calandra oryzae*." Jour. Agric. Sth. Aust. 44:307-8. 1941. (Reprint 309.)

Quick-breaking emulsions of fuel oil, red oil, white oil, and deodorized kerosene all were effective against *Calandra oryzae*. More stable emulsions, containing more emulsifier, killed fewer weevils.

- L. C. Birch. "The Influence of Temperatures above the Developmental Zero on the Development of the Eggs of *Austroicetes cruciata* Sauss. (Orthoptera)." Aust. Jour. Exp. Biol. & Med. Sci. 20:17-25. 1942. (Reprint 343.)

Diapause in the eggs of *A. Crucata* was eliminated slowly in the field from February onwards. By mid-June the eggs had reached normality with respect to development at temperatures above the developmental zero. In the field diapause was finally eliminated as katatrepsis was completed.

The temperature developmental curve for post-diapause eggs was sigmoidal. The lowest temperature at which eggs hatched was 13.5°C ., and the rate of development reached its maximum at 30.5°C .

- L. C. Birch and H. G. Andrewartha. "The Influence of Weather on Grasshopper Plagues in South Australia." Jour. Agric. Sth. Aust. 45:95-100. 1941. (Reprint 330.)

The weather conditions responsible for the collapse of the 1935-40 outbreak of the small plague grasshopper (*Austroicetes cruciata* Sauss.) have been analysed. An examina-

tion of meteorological records for six towns in the grasshopper belt showed that droughts as unfavourable to the grasshopper as that of 1940 have occurred four or five times in the past fifty years. The most serious damage to pastures and crops is done in years when the winter and spring rainfall is below average. In the last fifty years about one-third of the years were dry enough for severe grasshopper damage.

- L. C. Birch and H. G. Andrewartha. "The Influence of Moisture on the Eggs of *Austroicetes cruciata* Sauss. (Orthoptera), with Reference to their Ability to Survive Desiccation." Aust. Jour. Exp. Biol. & Med. Sci. 20: 1-8. 1942. (Reprint 342.)

The susceptibility of the eggs of *Austroicetes cruciata* to desiccation varied according to the stage of development of the embryo. It was greatest for newly laid eggs, and least for diapause eggs. It increased as diapause was gradually eliminated. A sudden increase in susceptibility to desiccation occurred in eggs in the field at the end of May. This is correlated with the elimination of diapause and an increase in the moisture content of the egg.

At all stages of development prolonged exposure to low humidity was necessary to kill even 50 per cent. of the eggs.

The mortality rate of eggs in diapause was shown to be related to total evaporation and the duration of the exposure to desiccation.

- J. Davidson. "Wheat Storage Problems in South Australia." Jour. Agric. Sth. Aust. 44: 123-36, 243-7, 346-52, 391-5. 1941. (Reprint 314.)

A description is given of the method of storing wheat in bags in large stacks at depots in South Australia as a war-time measure. The temperature, moisture content, and carbon dioxide content of the air in the intergranular and interbag spaces in these stacks are discussed in relation to the spoilage of the wheat and its infestation by grain weevils. An illustrated account is given of fifteen species of injurious insects found associated with stored wheat in South Australia.

- J. Davidson. "Flies, Fleas, and Lice." Med. Jour. Aust. 2: 111-6. 1942. (Reprint 360.)

This article is based on a lecture given to the Army Medical Services in Adelaide. It discusses the importance of flies, fleas, and lice as vectors of certain human diseases, in relation to the present conditions in Australia, associated with the nation at war. An outline is given of the practical measures which may be adopted to control these insects.

- J. Davidson. "On the Speed of Development of Insect Eggs at Constant Temperatures." Aust. Jour. Exp. Biol. & Med. Sci. 20: 233-9. 1942. (Reprint 364.)

An analysis has been made of data from experiments on three species of insects relating to the time taken for the eggs of these species to develop at different constant temperatures. When the reciprocal values of time are plotted against the appropriate temperature, the curve representing the trend of the observed points (which extend over the range of temperature at which complete development of the eggs to hatching can take place) can be divided into two parts. One part extends from the lowest temperature at which complete development to hatching can take place to the temperature value at which development proceeds at the fastest rate: this is defined as the "peak" temperature. The second part extends from the "peak" temperature to the highest temperature at which complete development of the eggs to hatching can take place. The observed points in the first part of the curve extend over 83 to 90 per cent. of the total temperature range. The trend of these points is faithfully

represented by an exponential curve of the form $\frac{1}{y} = \frac{K}{1 + ea^{-bx}}$ where $\frac{1}{y}$ is the reciprocal of the time required for the eggs of the insect to develop at a given temperature x . K , a and b are calculated parameters.

- H. Vevers Steele. "Some Observations on the Embryonic Development of *Austroicetes cruciata* Sauss. (Acrididae) in the Field." Trans. Roy. Soc. Sth. Aust. 65: 329-32. 1941. (Reprint 336.)

Eggs of *Austroicetes cruciata* were collected in the field at intervals between January and September. The embryonic development of the grasshopper is described with reference to its external morphology.

- D. C. Swan. "The Control of Ants." Jour. Agric. Sth. Aust. 44: 373-5. 1941. (Reprint 307.)

A brief account is given of the habits of the four common species of ants which are troublesome in South Australia (*Iridomyrmex rufoniger* Lowne, *I. detectus* Smith, *Monomorium pharaonis* L., *Camponotus consobrinus* s.sp. *obniger* Forel) and control measures which may be used.

- D. C. Swan. "The Control of Silverfish." Jour. Agric. Sth. Aust. 44: 420-2. 1941. (Reprint 312.)

A brief account is given of the habits of the common silverfish in houses in South Australia (*Otenolepisma longicaudata* Esch.) and methods of controlling it.

- D. C. Swan. "Notes on the Lesser Grain Borer (*Rhizopertha dominica* Fabr.) in South Australia." Jour. Agric. Sth. Aust. 45: 45-52. 1941. (Reprint 325.)

An account is given of observations made by the author on the biology and habits of the lesser grain borer (*Rhizopertha dominica* Fabr.) in bagged wheat stored in stacks in South Australia.

IX. CLIMATOLOGY.

- J. A. Prescott. "The Phase and Amplitude of Australian Mean Monthly Temperatures." Trans. Roy. Soc. Sth. Aust. 66: 46-9. 1942. (Reprint 354.)

The method of Fourier analysis has been applied to the data for mean monthly temperature for the 389 stations recorded in C.S.I.R. Pamphlet 42 (1933). For the twelve-monthly records can be satisfactorily substituted the annual mean, and the phase and amplitude of the first periodic term of the series. Maps of Australia are presented showing the isopleths for phase (expressed as temperature lag in days behind solar radiation) and amplitude. The maps show characteristic differences in phase between eastern and western Australia, and give expression to the differences in "continentality" between the temperature regimes of inland and coastal stations.

- D. C. Wark. "The Variability of the Length of the Rainfall Season and the Amount of Influential Rainfall in South Australia." Trans. Roy. Soc. Sth. Aust. 65: 249-53. 1941. (Reprint 335.)

The method employed by Trumble (Reprint 197: abstract in Report 1937-38) to determine the period and amount of effective rainfall, was applied to the rainfall and temperature data of individual seasons at twenty South Australian stations.

The variability of the rainfall period was expressed for each station as the mode, and the probable extreme values in 5, 10, and 20 per cent. of years.

Seasons were classified into types, based on the times of occurrence of dry spells during the rainfall period, and of effective rains during the summer dry period. Tables showing the percentages of years in which there occurred

- (a) periods of one, three, and five months with a continuously effective rainfall, and
- (b) periods of one, three, and five months of continuously dry weather, at different times of the year are included.

X. STATISTICAL METHOD.

- E. A. Cornish. "The Analysis of Quasi-Factorial Designs with Incomplete Data. 2. Lattice Squares." Jour. Aust. Inst. Agric. Sci. 7: 19-26. 1941. (Reprint 311.)

This is the second of a series of papers concerned with methods of analysing data derived from quasi-factorial designs in which complete sets of experimental values are missing. The paper deals with lattice square designs, and considers in detail the cases of a missing row (or column) and a missing treatment.

XI. MISCELLANEOUS.

- H. G. Andrewartha. "A Neglected Opportunity." Jour. Aust. Inst. Agric. Sci. 7: 1-6. 1941. (Reprint 310.)

This article expresses the need in Australia for studies in rural sociology and rural economics.

- A. R. Callaghan, H. G. Andrewartha, and K. Woodroffe. "Rural Economics." Jour. Aust. Inst. Agric. Sci. 8: 1-5. 1942. (Reprint 351.)

This is a report on "rural economics" prepared by a sub-committee of the South Australian branch of the Australian Institute of Agricultural Science.

- T. H. Strong. "The Use and Misuse of Land." Jour. Agric. Sth. Aust. 45: 203-6. 1941. (Reprint 332.)

A broadcast talk stressing the need for the conservation of natural resources in pastures and land, and the need for capital in the development of poor lands under scrub.

- D. C. Swan and V. A. Stephen. "An Injector for Liquid Fumigants." Jour. Aust. Inst. Agric. Sci. 8: 26. 1942. (Reprint 347.)

A description of a standard sheep-drenching gun adapted for use as an injector for liquid fumigants.

- R. E. Shapter. "A Preliminary Investigation of the Yield and Composition of the Oil Distilled from *Chenopodium ambrosioides* (Linn) var. *anthelminticum* (Gray)." Jour. C.S.I.R. 14: 201-8. 1941. (Reprint 331.)

Oil of *Chenopodium* has for many years been used as an anthelmintic, more particularly in veterinary practice against the round worm (*Ascaris suilla*) in pigs, and more recently it appeared in the British Pharmacopoeia for treatment in human beings of round worm (*Ascaris lumbricoides*) and hookworm (*Ankylostoma duodenale*). The oil has to a large extent the same application as thymol in the treatment of worm infestations, but has the disadvantage of being more toxic than the latter.

Owing to the shortage of the oil becoming more acute, wild plants of *C. ambrosioides* (Linn.) var. *anthelminticum* (Gray) were searched for and found. The oil was distilled from these, and also from plants grown from seed produced by the wild plants.

Results showing promise of satisfactory yields of oil from Australian-grown plants were obtained, the ascaridole content falling well within the amounts required by the British Pharmacopoeia. In other respects the oil varied from recognized standards, notably in that it was slightly dextrorotatory where as it is usually laevorotatory. This, however, is probably of little importance since the amount of ascaridole, which is regarded as the important anthelmintic principle, is within the recognized limits.

Records of Field Experimental Work

LIST OF FIELD EXPERIMENT RECORDS.

1. Permanent Rotation Experiment, 1926-42.
2. Influence of Grazed and Harvested Forage Crops on the Yield of Temporary Pasture and Wheat in Four-Course Rotations, 1937-42.
3. Effect of Fertilizers on the Yield of Wheat, Oats, Barley and Peas in Four-Course Rotations, 1937-42.
4. Effect of Time of Sowing and Seed Rate on the Yield of Liral Crown Flax, 1941.
5. Effect of Time of Sowing and Seed Rate on the Yield of Liral Crown Flax, 1937-41.
6. Effect of Harvesting at Various Stages of Growth on Total Yield and Seed Production of Liral Crown Flax, 1941.
7. Comparison of Liral Crown and Concurrent Flax Sown Early and Late, 1942.
8. Investigations of Linseed, 1931-32, 1940-42.
9. Establishment of Sown Pasture Under Different Cover Crops, 1941-42.
10. Influence of Top-Dressing on the Yield of Natural Pasture, 1925-42.
11. Carrying Capacity, Wool Production and Live-Weight Increases of Sheep on Natural and Seeded Pastures, 1940-42.
12. Effect of Superphosphate and Surface Cultivation on the Yield and Botanical Composition of a Seeded Pasture.
13. Effect of Differential Grazing Management on the Yield and Botanical Composition of a Seeded Pasture.
14. Yield Trials of New Crossbred Wheats, 1941.
15. Yield Trials of New Crossbred Wheats, 1942.

FORM AND TREATMENT OF TABLES.

In the succeeding tables the summarized records of the field experimental work carried out by the Waite Institute since its inception, and given in previous reports, have been supplemented by the data recorded in 1941 and 1942, and some earlier data not previously published.

A summary of the design and treatments employed appears at the head of each table.

Wherever possible, the data have been statistically analysed and the standard error values included. Two of the permanent field experiments (1 and 10) were commenced in 1925, prior to the adoption here of modern field designs, and no replication of treatment occurs in any one year. In others (2, 3, 11, 13), analysis awaits the completion of a term sufficient to enable differences in trends, and their relation with season, to be assessed.

The following is an example of one type of table:

<i>Mean yields of total produce in cwt. per ac. ± 1.16.</i>					
	Seed rate: lb. per ac.			Mean.	Difference.
Time of sowing.	40	60	80	± 1.218	± 1.722
E	52.54	56.72	57.59	55.61	—
M	50.57	55.90	56.12	54.20	— 1.41
L	50.25	52.97	54.60	52.60	— 1.60
Mean ± 0.672	51.12	55.19	56.10	54.14	—
Difference ± 0.950	—	+ 4.07	+ 0.91	—	—

The numbers in ordinary type are the mean yields of the treatments indicated at the headings of the columns and the left-hand margins of the rows. Thus 52·54 is the yield of total produce in cwt. per acre averaged over all plots sown early at 40 lb. seed per acre. The numbers in heavy type denote more general averages. Thus 55·61 is the yield in cwt. per acre averaged over all seed rates of the plots sown early. The general mean of all treatments is 54·14 cwt. per acre.

The standard errors (prefaced by the sign $\pm$) applicable to all comparisons of likely interest are included in the tables. As a general rule, it may be taken that a quantity is significant if it exceeds twice its standard error. Thus the mean increase in yield as a result of increasing the seed rate from 40 lb. to 60 lb. per acre is $4\cdot07 \pm 0\cdot950$ and is significant. The average decrease due to sowing late compared with sowing in mid-season is $1\cdot60 \pm 1\cdot722$ and is not significant.

In testing the difference between two quantities having the same standard error, it may be assumed that the difference is significant if it exceeds three times that standard error. Thus the difference between 52·54 and 56·72 is 4·18, and since this exceeds three times 1·16 there is a significant increase in yield due to the higher seed rate when the crop is sown early.

The areas of plots given in the tables denote areas at harvest. Unless otherwise specified, the experiments have been conducted at the Waite Institute.

1. PERMANENT ROTATION EXPERIMENT, 1926-42.

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per ac.: Sepoy wheat, 90 lb.; Early Burt oats, 70 lb.; Prior barley, 80 lb.; White Brunswick peas, 150 lb.; Wimmera rye-grass, 15 lb.; Sudan grass, 15 lb.

Basal dressing of 94 lb. per ac. superphosphate 1925-28; 187 lb. per ac. 1929-42.

Design: 31 plots, grouped in 12 rotations, so that each course of the 12 rotations is represented every year. Rotations as per table.

Area of each plot = $\frac{1}{4}$ acre.

(a) Total yields of crop in cwt. per ac., Rye-grass pasture in cwt, dry matter per ac., and Sudan grass in cwt. green fodder per ac.

Rotation.	Crop.	Mean. 1926-30.	Mean. 1931-35.	Mean. 1936-40.	Mean. 1926-40.	1941.	1942.	Mean. 1926-42.
1	Fallow							
	Wheat	61·60	47·39	45·00	51·33	64·88	34·62	51·15
2	Peas	29·85	45·70	28·91	34·81	50·00	34·62	35·70
	Wheat	59·59	29·40	32·32	40·43	55·76	27·14	40·56
3	Fallow							
	Wheat	66·72	53·64	52·97	57·78	81·10	40·47	58·13
	Rye-grass	41·55	16·02	22·98	25·80	50·41	24·93	27·28
4	Fallow							
	Wheat	67·18	55·20	52·69	58·35	74·00	27·28	63·33
	Oats	63·21	32·96	33·79	43·32	61·33	7·62	42·28
5	Fallow							
	Wheat	67·72	57·66	57·48	60·95	77·04	39·79	60·66
	Peas	34·56	38·48	30·79	34·61	54·29	30·96	35·55
6	Fallow							
	Wheat	67·05	57·37	57·42	60·61	77·55	39·04	60·34
	Barley	65·92	37·97	37·57	47·15	55·25	16·67	45·84
7	Wheat	41·24	17·62	20·66	26·51	35·48	14·29	26·32
8	Peas	34·03	37·75	35·60	35·80	55·71	46·67	37·61
	Wheat	66·54	34·81	39·28	46·87	72·99	31·43	47·50
	Oats	61·08	28·24	25·26	38·19	60·82	3·81	37·50
9	Peas	33·03	38·42	35·55	35·67	57·62	46·19	37·58
	Wheat	67·19	38·06	41·70	48·98	73·50	39·04	49·84
	Barley	64·19	33·26	38·81	45·42	58·80	19·66	44·69

Rotation.	Crop.	Mean. 1926-30.	Mean. 1931-35.	Mean. 1936-40.	Mean. 1926-40.	1941.	1942.	Mean. 1926-42.
10	Fallow							
	Wheat	75.53	63.85	63.20	67.52	80.59	39.04	66.62
	Oats	68.73	43.30	42.54	51.52	76.54	10.47	50.58
	Rye-grass	44.92	21.65	23.93	29.11	60.93	36.78	31.58
11	Sudan grass	23.75	0.83	49.22	24.60	18.57	40.00	25.15
	Wheat	66.28	45.18	38.93	50.13	69.95	40.96	51.59
12	Fallow							
	Wheat	66.76	51.83	48.77	55.79	78.06	34.36	55.84

(b) Grain yields in bushels per ac.

Rotation.	Crop.	Mean. 1926-30.	Mean. 1931-35.	Mean. 1936-40.	Mean. 1926-40.	1941.	1942.	Mean. 1926-42.
1	Fallow							
	Wheat	40.22	30.52	33.09	34.61	37.64	30.22	34.53
2	Peas	16.03	19.13	20.45	18.54	38.86	29.90	20.40
	Wheat	37.77	20.30	23.12	27.06	35.35	23.62	27.35
3	Fallow							
	Wheat	40.85	37.10	38.90	38.95	41.84	34.67	38.87
	Rye-grass*							
4	Fallow							
	Wheat	40.33	34.97	35.78	37.02	40.45	14.63	35.91
	Oats	67.18	38.05	37.17	47.47	60.62	1.33	45.53
5	Fallow							
	Wheat	39.67	38.76	40.38	39.60	36.06	32.83	38.99
	Peas	21.44	30.90	24.23	25.52	42.44	25.14	26.50
6	Fallow							
	Wheat	40.40	35.99	41.07	39.15	44.78	29.40	38.91
	Barley	63.23	40.21	40.15	47.86	58.39	16.72	46.65
7	Wheat	24.94	9.12	12.60	15.56	21.12	3.87	15.20
8	Peas	20.18	30.59	29.31	26.69	46.35	42.57	28.78
	Wheat	41.08	24.38	27.98	31.15	43.29	23.94	31.44
	Oats	62.06	29.15	27.73	39.65	58.85	0.29	38.47
9	Peas	21.43	30.29	29.89	27.20	48.76	42.16	29.35
	Wheat	41.09	26.97	31.29	33.12	44.30	32.95	33.76
	Barley	63.80	33.14	40.97	45.97	60.30	18.55	45.20
10	Fallow							
	Wheat	45.09	43.67	45.60	44.79	40.75	31.87	43.79
	Oats	67.68	52.05	51.81	57.18	78.46	3.33	55.27
	Rye-grass*							
11	Sudan grass*							
	Wheat	41.08	32.29	29.08	34.15	27.27	33.71	33.72
12	Fallow							
	Wheat	42.34	35.61	36.14	38.03	44.03	30.22	37.92

* Yields (cwt. per ac.) in previous table.

2. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS.

Rotations:

A	B	C	D	E
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Variety of crop and seed rate per ac.:

Sepoy wheat, 90 lb.; Cape barley, 80 lb.; Mulga oats, 70 lb.; White Brunswick peas, 150 lb.; Clover mixture (Mt. Barker subterranean clover, Dwalganup subterranean clover, and barrel medic), 10 lb. per ac. each; Wimmera rye-grass, 10 lb. per ac. as pasture.

Basal fertilizer dressing: 2 cwt. superphosphate per ac. to all crops including pasture.

Forage crop treatment: G = grazed. H = harvested.

Design: 60 main plots in 4 groups of 15 plots, each representing one course of the rotation. The groups of 15 plots are divided into 3 randomized blocks of 5 plots, each representing a different rotation. Each plot is subdivided into halves; on one the forage crop is grazed, and on the other it is harvested.

Area of main plots = $\frac{1}{6.94}$ acre.

(a) *Yields of forage crops (air-dry).*

Year.	A Peas.			B Clover.			C Barley.			D Oats.		
	G		H	G		H	G		H	G		H
	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)
1937	55.37	49.89	39.83	25.07	24.11	17.92	19.80	21.10	15.84	20.11	23.38	
1938	42.09	41.67	23.53	16.98	10.27	26.35	29.82	28.73	13.22	25.62	31.92	
1939	49.54	49.47	40.74	48.57	44.63	27.97	38.19	41.77	38.17	37.24	38.84	
1940	41.67	30.65	25.50	8.16	8.09	15.17	14.62	15.66	16.91	15.73	22.26	
1941	52.03	53.57	42.90	39.08	48.17	22.89	20.49	19.86	20.37	25.88	22.17	
1942	55.79	36.47	31.55	38.83	19.27	15.79	13.75	14.72	3.51	1.89	1.47	
Mean	49.42	43.62	34.01	29.45	25.76	21.02	22.78	23.64	18.00	21.08	23.34	

(b) *Yields of temporary pasture (oven-dry) in cwt. per ac.*

Year.	A After peas.		B After clover.		C After barley.		D After oats.	
	G	H	G	H	G	H	G	H
	33.23*		19.28*		19.41*		18.14*	
1937								
1938	30.05	20.67	22.77	19.30	13.66	8.41	11.18	8.44
1939	58.90	46.37	24.59	23.25	23.23	13.91	21.78	13.63
1940	36.09	23.79	26.53	16.87	18.86	8.32	12.26	5.78
1941	58.56	45.30	22.43	26.47	21.02	17.04	16.05	14.91
1942	97.23	34.66	24.13	17.87	13.00	12.65	12.36	11.32
Mean	52.34	34.00	23.29	20.51	18.20	13.29	15.30	12.04

* Forage crops were not differentially treated in 1936; pasture plots therefore were not split in 1937.

(c) *Yields of wheat in bushels per ac.*

Year.	A After peas.		B After clover.		C After barley.		D After oats.		E After fallow-wheat.	
	G	H	G	H	G	H	G	H	G	H
1937	43.75	43.71	37.17	39.39	40.16	39.93	38.66	43.15	40.01	39.26
1938	39.64	42.01	37.71	39.49	39.68	40.99	37.54	39.89	30.51	32.20
1939	49.56	50.68	48.14	45.19	46.08	45.11	45.67	44.27	38.56	38.19
1940	48.95	47.91	51.69	49.20	51.67	49.30	50.53	47.62	50.72	47.47
1941	42.11	43.25	41.95	42.82	42.28	42.16	43.15	39.74	39.85	40.26
1942	52.37	49.53	48.80	43.56	37.24	31.57	38.05	34.38	40.34	36.12
Mean	46.06	46.18	44.24	43.28	42.85	41.51	42.27	41.51	40.00	38.92

Statistical analysis of the data from this experiment awaits completion of two cycles of the rotations.

3. EFFECT OF SUPERPHOSPHATE, NITROGEN AND LIME ON THE YIELD OF WHEAT, OATS, BARLEY AND PEAS IN FOUR-COURSE ROTATIONS.

Rotations:

A	B	C	D
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Variety of crop and seed rate per ac.:

Seawari wheat, 90 lb.; Mulga oats, 70 lb.; Prior barley, 80 lb.; White Brunswick peas, 150 lb. Pasture: Wimmera rye-grass, 3 lb. + Mt. Barker subterranean clover, 6 lb. + Dwalganup subterranean clover, 6 lb.

Fertilizer treatments:

Superphosphate: $P_0 = \text{nil}$, $P_1 = 1$ cwt. per ac., $P_2 = 2$ cwt. per ac.

Sulphate of ammonia: $N_0 = \text{nil}$, $N_1 = 1$ cwt. per ac., $N_2 = 2$ cwt. per ac.

Lime (calcium hydroxide): $L_0 = \text{nil}$, $L_1 = 2\frac{1}{2}$ cwt. per ac., $L_2 = 5$ cwt. per ac.

All combinations of superphosphate, sulphate of ammonia, and lime are applied to the cereal crops and peas. The pastures receive no fertilizer.

Design: 432 plots, in 4 groups of 108 plots, one group to each rotation. Each of these groups of 108 plots is subdivided into 4 sections of 27 plots, and these sections represent the four courses of each rotation in every year. Each section of 27 plots is subdivided into 3 randomized blocks of 9 plots for the application of the fertilizer treatments. This subdivision confounds a pair of degrees of freedom for second order interaction with soil differences.

Area of a single plot = $\frac{1}{77}$ th acre.

Yields of grain in bushels per ac.

Rotation A.											
Mean of all lime.				Mean of all nitrogen.				Mean of all phosphate.			
N_0	N_1	N_2		L_0	L_1	L_2	Mean	N_0	N_1	N_2	
<i>Wheat, 1941.</i>											
P_0	38.93	39.03	36.68	37.11	39.78	37.75	38.21	L_0	38.82	36.36	32.94
P_1	39.46	38.18	34.44	35.93	39.46	36.68	37.36	L_1	39.89	38.71	36.04
P_2	38.39	34.43	34.22	35.08	35.40	36.57	35.68	L_2	38.07	36.57	36.36
Mean	38.93	37.22	35.11	36.04	38.21	37.00	37.08				
<i>Wheat, 1942.</i>											
P_0	44.06	41.17	48.98	42.46	47.48	44.27	44.74	L_0	41.92	43.53	48.77
P_1	44.60	41.60	50.05	45.13	47.38	43.74	45.41	L_1	47.38	43.85	48.66
P_2	43.42	46.41	47.16	46.63	45.02	45.34	45.67	L_2	42.78	41.82	48.77
Mean	44.03	43.06	48.73	44.74	46.63	44.45	45.27				
<i>Wheat, 1937-42.</i>											
P_0	42.82	42.69	42.87	41.65	44.11	42.62	42.79	L_0	43.64	42.80	42.41
P_1	45.36	43.93	43.41	43.58	44.25	44.87	44.23	L_1	44.67	43.79	43.27
P_2	43.84	43.63	42.84	43.62	43.37	43.33	43.44	L_2	43.72	43.66	43.44
Mean	44.01	43.42	43.04	42.95	43.91	43.61	43.48				
<i>Peas, 1941.</i>											
P_0	47.97	51.28	48.82	51.71	50.43	45.93	49.36	L_0	53.15	52.62	52.41
P_1	53.26	52.57	53.05	53.21	51.06	54.06	52.96	L_1	50.75	52.57	50.05
P_2	52.57	52.19	50.85	53.26	51.33	51.01	51.87	L_2	49.89	50.85	50.26
Mean	51.26	52.01	50.91	52.73	51.12	50.34	51.40				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N ₀	N ₁	N ₂	L ₀	L ₁	L ₂	Mean	N ₀	N ₁	N ₂	
<i>Peas, 1942.</i>											
P ₀	39.46	42.88	36.58	40.75	41.39	36.79	39.64	L ₀	44.70	46.31	45.99
P ₁	47.59	49.09	47.38	47.59	50.91	45.56	48.02	L ₁	47.27	46.95	45.77
P ₂	49.94	47.91	46.63	48.77	47.70	48.02	48.16	L ₂	45.02	46.52	38.82
Mean	45.67	46.63	43.53	45.70	46.66	43.46	45.27				
<i>Peas, 1937-42.</i>											
P ₀	34.15	35.77	34.46	35.60	35.37	33.42	34.80	L ₀	38.48	38.48	36.58
P ₁	39.77	39.19	37.67	38.57	38.95	39.03	38.88	L ₁	37.73	37.59	37.42
P ₂	40.41	38.41	37.88	39.38	38.34	38.97	38.90	L ₂	38.12	37.28	36.01
Mean	38.11	37.79	36.67	37.85	37.58	37.14	37.52				
Rotation B.											
<i>Wheat, 1941.</i>											
P ₀	39.14	34.86	36.15	37.97	37.64	34.54	36.72	L ₀	39.89	39.57	37.54
P ₁	40.85	40.96	40.10	41.39	40.11	40.43	40.64	L ₁	40.53	39.46	37.11
P ₂	40.75	39.89	35.93	37.64	39.36	39.57	38.86	L ₂	40.32	36.68	37.54
Mean	40.25	38.57	37.39	39.00	39.03	38.18	38.74				
<i>Wheat, 1942.</i>											
P ₀	32.62	32.19	30.69	31.12	31.66	32.73	31.83	L ₀	31.01	36.68	38.61
P ₁	36.90	34.76	35.29	39.36	32.30	35.29	35.65	L ₁	37.32	31.44	28.77
P ₂	35.40	33.79	37.32	35.83	33.58	37.11	35.51	L ₂	36.58	32.62	35.93
Mean	34.97	33.58	34.44	35.43	32.51	35.04	34.33				
<i>Wheat, 1936-42.</i>											
P ₀	35.05	34.13	35.28	34.33	34.58	35.55	34.82	L ₀	37.61	38.87	38.76
P ₁	39.55	39.79	41.24	40.86	39.28	40.44	40.19	L ₁	38.43	37.30	38.39
P ₂	39.56	40.55	40.65	39.78	40.28	40.71	40.25	L ₂	38.41	38.29	40.01
Mean	38.05	38.16	39.05	38.32	38.04	38.90	38.42				
<i>Oats, 1941.</i>											
P ₀	60.48	72.35	75.56	66.49	69.30	72.59	69.46	L ₀	58.31	75.00	78.84
P ₁	63.04	75.31	87.91	76.76	81.65	67.86	75.42	L ₁	59.35	70.34	85.34
P ₂	51.81	68.90	81.17	68.90	64.08	68.90	67.29	L ₂	57.67	71.23	80.45
Mean	58.45	72.19	81.55	70.72	71.68	69.78	70.73				
<i>Oats, 1942.</i>											
P ₀	37.21	51.98	62.24	48.61	49.57	53.26	50.48	L ₀	35.12	49.41	65.61
P ₁	34.01	49.89	63.04	49.57	47.16	50.21	48.98	L ₁	33.21	51.33	63.53
P ₂	36.58	52.14	68.02	51.98	51.33	53.42	52.24	L ₂	39.46	53.26	64.17
Mean	35.93	51.33	64.43	50.05	49.36	52.30	50.57				
<i>Oats, 1936-42.</i>											
P ₀	52.33	63.64	70.92	62.07	62.10	62.73	62.30	L ₀	53.26	66.02	76.91
P ₁	54.21	66.53	77.65	67.87	65.53	64.98	66.13	L ₁	52.92	64.58	74.43
P ₂	52.37	66.39	77.02	66.26	64.30	65.24	65.26	L ₂	52.72	65.96	74.28
Mean	52.97	65.52	75.21	65.40	63.98	64.32	64.56				
Rotation C.											
<i>Wheat, 1941.</i>											
P ₀	38.93	36.68	35.18	37.32	35.29	38.18	36.93	L ₀	41.17	40.21	38.82
P ₁	43.53	40.96	40.64	42.35	42.56	40.21	41.71	L ₁	40.53	40.32	38.82
P ₂	39.36	42.44	37.32	40.53	41.82	36.58	39.64	L ₂	40.10	39.36	35.51
Mean	40.60	39.96	37.72	40.07	39.89	38.32	39.43				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N ₀	N ₁	N ₂	L ₀	L ₁	L ₂	Mean		N ₀	N ₁	N ₂
Wheat, 1942.											
P ₀	40.85	34.65	36.04	35.93	36.36	39.25	37.18	L ₀	43.74	40.64	42.35
P ₁	43.53	39.57	47.70	45.02	44.49	41.28	43.60	L ₁	42.78	37.11	43.63
P ₂	42.56	42.99	44.17	45.77	42.67	41.28	43.24	L ₂	40.43	39.46	41.92
Mean	42.31	39.07	42.64	42.24	41.17	40.60	41.34				
Wheat, 1936-42.											
P ₀	32.50	32.10	32.77	32.06	32.37	32.94	32.46	L ₀	37.47	37.00	37.23
P ₁	40.05	38.73	40.24	39.41	39.77	39.83	39.67	L ₁	37.21	37.43	37.73
P ₂	39.74	41.39	40.04	40.24	40.23	40.69	40.38	L ₂	37.62	37.75	38.09
Mean	37.43	37.40	37.69	37.23	37.45	37.82	37.51				
Barley, 1941.											
P ₀	55.70	58.01	68.27	59.67	60.44	61.86	60.66	L ₀	44.15	58.90	70.07
P ₁	44.40	62.63	72.51	57.88	59.67	61.98	59.85	L ₁	49.41	59.16	69.94
P ₂	46.20	59.03	71.10	55.57	58.39	62.37	58.78	L ₂	52.74	61.60	71.87
Mean	48.77	59.89	70.63	57.71	59.50	62.07	59.76				
Barley, 1942.											
P ₀	27.08	31.44	42.09	35.68	32.85	32.08	33.54	L ₀	30.80	33.75	41.96
P ₁	30.41	36.45	43.25	33.62	38.50	37.99	36.70	L ₁	27.59	35.55	44.15
P ₂	35.93	34.78	42.35	37.22	35.93	39.91	37.69	L ₂	35.03	33.37	41.58
Mean	31.14	34.22	42.56	35.51	35.76	36.66	35.98				
Barley, 1936-42.											
P ₀	41.07	45.42	51.55	45.73	46.58	45.72	46.01	L ₀	40.56	47.80	54.43
P ₁	41.12	51.28	55.96	48.16	49.33	50.87	49.45	L ₁	41.81	49.10	55.37
P ₂	42.87	49.65	56.01	48.90	50.35	49.27	49.51	L ₂	42.67	49.44	53.71
Mean	41.69	48.78	54.50	47.60	48.75	48.62	48.32				
Rotation D.											
Wheat, 1941.											
P ₀	38.29	36.90	37.64	38.93	38.50	35.40	37.61	L ₀	40.96	40.32	36.68
P ₁	41.82	39.25	38.50	40.00	39.78	39.78	39.85	L ₁	41.28	38.07	37.86
P ₂	40.85	39.25	35.51	39.03	38.93	37.64	38.54	L ₂	38.71	37.00	37.11
Mean	40.32	38.46	37.22	39.32	39.07	37.61	38.67				
Wheat, 1942.											
P ₀	45.77	43.21	42.99	43.10	44.92	43.95	43.99	L ₀	47.70	47.27	45.45
P ₁	45.56	46.52	45.77	49.09	45.34	43.42	45.95	L ₁	45.67	47.06	44.28
P ₂	46.20	47.70	46.41	48.23	46.73	45.34	46.77	L ₂	44.17	43.10	45.45
Mean	45.84	45.81	45.06	46.81	45.67	44.24	45.57				
Wheat, 1937-42.											
P ₀	40.86	40.17	39.84	40.40	40.27	40.19	40.29	L ₀	43.19	42.77	41.47
P ₁	42.91	43.50	43.61	43.62	43.43	42.97	43.34	L ₁	43.07	42.54	41.39
P ₂	43.54	43.70	42.02	43.40	43.29	42.57	43.09	L ₂	41.05	42.05	42.63
Mean	42.44	42.45	41.83	42.48	42.33	41.91	42.24				
Wheat (stubble-sown), 1941.											
P ₀	36.90	38.61	35.40	36.90	36.90	37.11	36.97	L ₀	38.71	39.25	41.49
P ₁	35.83	40.85	44.70	41.49	40.32	39.57	40.46	L ₁	35.18	39.14	42.67
P ₂	35.93	41.82	44.28	41.07	39.78	41.17	40.67	L ₂	34.76	42.88	40.21
Mean	36.22	40.43	41.46	39.82	39.00	39.28	39.37				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N ₀	N ₁	N ₂	L ₀	L ₁	L ₂	Mean	N ₀	N ₁	N ₂	
Wheat (stubble-sown), 1942.											
P ₀	24.60	28.34	35.40	29.73	30.91	27.70	29.45	L ₀	23.31	28.02	33.79
P ₁	23.63	28.13	33.47	28.55	27.59	29.09	28.41	L ₁	25.35	29.52	33.58
P ₂	23.21	27.48	34.54	26.84	29.94	28.45	28.41	L ₂	22.78	26.42	36.04
Mean	23.81	27.98	34.47	28.38	29.48	28.41	28.76				
Wheat (stubble-sown), 1937-42.											
P ₀	29.97	33.75	35.72	33.32	33.16	32.96	33.15	L ₀	32.36	35.43	39.42
P ₁	31.98	37.60	41.18	37.34	37.03	36.89	36.92	L ₁	31.42	35.82	39.11
P ₂	32.72	36.74	41.73	36.55	36.65	37.98	37.06	L ₂	30.89	36.84	40.11
Mean	31.55	36.03	39.55	35.74	35.45	35.95	35.71				
Yields of temporary pasture (oven-dry) in cwt. per ac.											
		N ₀	N ₁	N ₂	P ₀	P ₁	P ₂		L ₀	L ₁	L ₂
Rotation A.											
	1941		29.93	31.86	29.91	29.02	30.24	32.45	30.01	30.42	31.27
	1942		33.64	33.60	35.40	32.11	34.89	35.64	33.38	35.21	34.05
Mean	1938-42		30.75	32.01	32.08	29.41	32.07	33.36	30.82	31.54	32.47
Rotation B.											
	1941		30.60	28.47	29.61	28.35	29.77	30.56	28.21	29.87	30.60
	1942		14.93	12.90	15.32	12.79	14.75	15.61	14.57	13.88	14.70
Mean	1938-42		22.44	21.10	22.25	20.63	21.98	23.18	21.62	21.91	22.26
Rotation C.											
	1941		29.24	29.94	29.93	27.24	30.77	31.10	27.00	30.24	31.87
	1942		24.87	25.73	25.42	22.66	25.89	27.47	22.86	25.52	27.64
Mean	1938-42		24.83	25.27	25.86	22.25	25.66	28.06	23.80	25.03	27.13
Rotation D.											
	1941		39.59	39.66	41.95	35.38	41.86	43.96	39.02	41.45	40.73
	1942		32.50	27.39	29.67	27.50	29.48	32.58	28.48	30.25	30.83
Mean	1938-42		29.23	27.99	29.42	26.63	28.85	31.17	27.57	29.50	29.58

4. EFFECT OF TIME OF SOWING AND SEED RATE ON THE YIELD OF LIRAL CROWN FLAX, 1941.

Seed rate: 40, 60, and 80 lb. per ac.

Superphosphate: Basal dressing of 1½ cwt. per ac.

Time of sowing: E = sown early, 26th May. M = sown 4th June. L = sown 13th June.

Treatments: All combinations of time of sowing and seed rate.

Design: 4 randomized blocks of early and 2 late sowings. The 3 seed rates randomized within each main plot. Total plots, 36.

Area of main plot = ¾₉th acre; area of sub-plot = ¼₉th acre.

Mean yields of seed in bushels per ac. ± 1.00.

Time of sowing.	Seed rate: lb. per ac.			Mean.	Difference.
	40	60	80		
E	11.02	10.52	8.78	10.11	—
M	11.01	10.26	8.56	9.94	— 0.17
L	14.59	12.10	9.88	12.19	+ 2.25
Mean ± 0.183	12.21	10.96	9.07	10.75	—
Difference ± 0.259	—	— 1.25	— 1.89	—	—

Significant decrease with increasing seed rate.

Late sowing shows significant increase over the two earlier sowing dates.

Mean yields of total produce in cwt per ac. ± 1.16 .

Time of sowing.	Seed rate: lb. per ac.			Mean.	Difference.
	40	60	80		
E	52.54	56.72	57.59	55.61	—
M	50.57	55.90	56.12	54.20	— 1.41
L	50.25	52.97	54.60	52.60	— 1.60
Mean ± 0.672	51.12	55.19	56.10	54.14	—
Difference ± 0.950	—	+ 4.07	+ 0.91	—	—

Significant increase with increasing seed rate.

5. EFFECT OF TIME OF SOWING AND SEED RATE ON THE YIELD OF LIRAL CROWN FLAX, 1937-41.

Seed rate: 40, 60, and 80 lb. per ac.

Superphosphate: Basal dressing of 1-2 cwt. per ac.

Time of sowing: E = sown early (May). L = sown late (June, 1937-38, 1940-41; early July, 1939).

Treatments: All combinations of times of sowing and seed rate.

Design: 4 randomized blocks of early and late sowings. The 3 seed rates randomized within each main plot. Total plots: 36 to 64 according to the year; 24 plots with the same treatments throughout have formed the basis of the comparisons listed below.

Area of main plot = $\frac{3}{64}$ th to $\frac{3}{49}$ th acre; area of sub-plot = $\frac{1}{64}$ th to $\frac{1}{49}$ th acre.

Mean yields of seed in bushels per ac. ± 0.433 .

	Early sown.			Late sown.			Mean.	Difference.
	Seed rate: lb. per ac.			Seed rate: lb. per ac.				
	40	60	80	40	60	80		
							± 0.177	± 0.250
1937	13.58	11.99	9.75	7.81	7.67	7.50	9.71	—
1938	8.79	8.73	7.64	6.18	6.23	7.08	7.44	— 2.27
1939	13.63	12.17	13.06	6.16	6.62	6.93	9.76	+ 2.32
1940	10.43	10.03	9.08	7.04	6.70	6.75	8.33	— 1.43
1941	11.03	10.52	8.78	14.59	12.10	9.88	11.15	+ 2.82
Mean ± 0.253	11.49	10.69	9.66	8.35	7.86	7.63	—	—
Difference ± 0.358	—	— 0.80	— 1.03	— 1.31	— 0.49	— 0.23	—	—

Significant decreases due to increasing seed rate.

Significant decrease due to late sowing.

Significant differences due to season.

Mean yields of total produce in cwt. per ac. ± 1.353 .

	Early sown.			Late sown.			Mean.	Difference.
	Seed rate: lb. per ac.			Seed rate: lb. per ac.				
	40	60	80	40	60	80		
							± 0.552	± 0.781
1937	48.31	49.75	52.13	36.59	36.72	40.28	43.96	—
1938	47.69	50.53	51.16	30.49	31.42	36.72	41.34	— 2.62
1939	52.78	57.04	60.37	26.88	31.00	32.87	43.48	+ 2.14
1940	52.00	55.92	60.54	37.22	40.06	40.30	47.67	+ 4.19
1941	52.54	56.72	57.59	50.25	52.97	54.60	54.11	+ 6.44
Mean ± 0.648	50.66	53.99	56.36	36.29	38.43	40.95	—	—
Difference ± 0.916	—	+ 3.33	+ 2.37	— 20.07	+ 2.14	+ 2.52	—	—

Significant increases due to increasing seed rate.

Significant decrease due to late sowing.
Significant increases due to increasing seed rate.

Significant differences due to season.

Mean yields of seed and total produce.

Seed (bushels per ac.) ± 0.253 .					
Seed rate: lb. per ac.			Mean.	Difference.	
Time of sowing.	40	60	80	± 0.121	± 0.171
E	11.49	10.69	9.66	10.61	—
L	8.35	7.86	7.63	7.95	— 2.66
Mean ± 0.179	9.92	9.27	8.65	—	—
Difference ± 0.253	—	— 0.65	— 0.62	—	—

Total produce (cwt. per ac.) ± 0.648 .					
Seed rate: lb. per ac.			Mean.	Difference.	
Time of sowing.	40	60	80	± 0.684	± 0.967
E	50.66	53.99	56.36	53.67	—
L	36.29	38.43	40.95	38.56	— 15.11
Mean ± 0.458	43.47	46.21	48.66	—	—
Difference ± 0.648	—	+ 2.74	+ 2.45	—	—

Main significant effect is reduction due to late seeding.

6. EFFECT OF HARVESTING AT VARIOUS STAGES OF GROWTH ON TOTAL YIELD AND SEED PRODUCTION OF FLAX, 1941.

Variety: Liral Crown.

Fertilizer: 1 cwt. per ac.

Design: randomized block.

Seed rate: 68 lb. per ac.

Sowing date: 28th May.

		Means of six plots.				
Date of harvest.	Stage of growth.	Total yield (cwt.) per ac. ± 1.34	Seed (bush.) per ac. ± 0.31	Weight 200 seeds (gm.) ± 0.03	% viable seed.	% oil content air-dry seed.
17. 9.41	Appearance of first flowers	32.67	—	—	—	—
25. 9.41	Early flowering	44.37	—	—	—	—
2.10.41	Mid-flowering. Some bolls fully formed	49.42	0.04	.543	64.0	—
9.10.41	Flowering almost complete. Yellowish tinge at base	51.44	0.56	.555	78.2	—
16.10.41	Flowering complete. About one-third stem yellow	56.73	3.35	.583	79.7	26.1
23.10.41	Stems yellow. Leaves fallen from lower half	56.07	7.03	.668	93.3	29.5
30.10.41	Bolls commencing to change colour	59.95	9.00	.837	98.8	31.2
6.11.41	Most leaves fallen. Bolls rattling	57.16	9.07	.925	95.8	28.7
13.11.41	All leaves fallen. Seed becoming firm	57.82	10.07	.944	97.3	29.0
20.11.41	Seed maturing	58.83	9.34	.943	96.3	35.0
27.11.41	Seed fully matured. Some bolls fallen	53.12	8.42	.932	94.2	35.0
4.12.41	Plants drying and bolls falling	51.52	7.33	.946	94.5	34.4
11.12.41	Plants dry, brittle and harsh. Many bolls fallen	48.15	5.11	.940	89.7	34.4
18.12.41	Plants dry, brittle and harsh. Many bolls fallen	50.17	5.58	.955	90.3	32.6

7. YIELD OF LIRAL CROWN AND CONCURRENT FLAX, SOWN EARLY AND LATE, 1942.

Varieties: Liral Crown and Concurrent.

Seed rate: 70 lb. per ac.

Superphosphate: Basal dressing, 1 cwt. per ac.

Time of sowing: E = 21st May. L = 24th June.

Treatments: 4 combinations of variety and seed rate.

Design: 3 randomized blocks, each containing 2 main plots sown early and late, and each of these made up of 4 sub-plots. The 4 sub-plots sown to 2 varieties in duplicate, and restricted within 2 sub-blocks.

Area of sub-block = $\frac{2}{3}$ rd acre; area of unit plot = $\frac{1}{63}$ rd acre.

Mean yields of seed in bushels per ac. ± 0.421 .

Variety	Sowing date.		Mean of 2 sowing dates	Difference
	E	L	± 0.282	± 0.399
Liral Crown	7.39	2.22	4.81	—
Concurrent	7.14	1.75	4.45	— 0.36
Mean of 2 varieties ± 0.340	7.27	1.99	—	—
Difference ± 0.481	—	— 5.28	—	—

Significant difference in favour of early sowing.

Mean yields of total produce in cwt. per ac. ± 2.009 .

Variety	Sowing date.		Mean of 2 sowing dates	Difference
	E	L	± 0.673	± 0.952
Liral Crown	56.30	30.94	43.62	—
Concurrent	56.68	27.11	41.90	— 1.72
Mean of 2 varieties ± 1.781	56.49	29.03	—	—
Difference ± 2.519	—	— 27.46	—	—

Significant difference in favour of early sowing.

8. INVESTIGATIONS OF LINSEED, 1931–32, 1940–42.

Varieties: 1931, Argentine, New Zealand, Calcutta; 1932, New Zealand; 1940–41, strains as listed; 1942, Punjab (two strains), Walsh.

Times of sowing: 22nd May, 16th June, 1931; 2nd May, 1932; 22nd May, 1940; 28th May, 1941; 21st May, 8th June, 16th and 30th July, 1942.

Fertilizer: 1–2 cwt. superphosphate per ac. on fallow.

Design: 4 replications in randomized blocks.

Size of plots: $\frac{1}{28}$ th to $\frac{1}{60}$ th acre.

Yields in bushels per ac.

1931.

Variety.	Sown 22nd May. Seed rate: lb. per ac.			Sown 16th June. Seed rate: lb. per ac.		
	30	45	60	30	45	60
	Means of 4 plots ± 0.57 .					
Argentine	4.79	4.77	5.35	1.69	2.69	2.50
New Zealand	2.92	4.64	3.13	1.79	2.08	2.26

Calcutta linseed sown on 22nd May at 45 lb. per ac. yielded 9.61 bushels per ac.

1932.

Sown 2nd May (38 lb. seed per ac.).

Variety.	No fertilizer.	2 cwt. super. per ac.	2 cwt. super. per ac. + 2 cwt. sulph. amm. per ac.	Mean.
New Zealand				
Mean ± 0.97	14.31	17.59	23.44	18.44
Difference ± 1.36	—	3.28	5.85	—

1940.

Sown 22nd May (40 lb. seed per ac.).

Varieties: A, Punjab; B, Abyssinian; C, Argentine; D, Newland; E, Redwing; F, Bison; G, Victorian; H, U.S. Hybrid; I, New Zealand; J, Ottawa.

	A	B	C	D	E	F	G	H	I	J	Mean.
Mean ± 0.35	15.75	13.64	9.65	8.81	8.70	8.12	8.10	7.91	7.35	6.66	9.47
% oil content	37.75	39.24	39.29	38.83	38.07	37.59	38.26	36.72	38.15	38.66	38.26

1941.

Sown 28th May (40 lb. seed per ac.).

Varieties: A, Punjab 23; B, Punjab 5; C, Punjab; D, Abyssinian; E, U.S. Hybrid; F, Newland; G, Bison; H, Redwing; I, New Zealand; J, Victorian; K, Ottawa.

	A	B	C	D	E	F	G	H	I	J	K	Mean.
Mean ± 0.71	23.19	22.95	21.74	16.75	12.64	12.32	11.90	10.46	8.94	8.53	7.73	14.29
% oil content	43.26	43.59	39.77	39.74	—	—	—	—	—	—	—	—

1942.

Variety.	Sown 21st May.	Sown 8th June.	Sown 16th July.	Sown 30th July.
Punjab	15.68	5.38	1.67	0.42
Punjab 23	10.42	3.68	0.76	0.32
Walsh	4.31	2.77	1.21	0.98

Analysis of May and June seedings.

	Punjab.	Punjab 23.	Walsh.	Mean ± 0.341	Difference ± 0.482
21st May	15.68	10.42	4.31	10.14	—
8th June	5.38	3.68	2.77	3.94	— 6.20
Mean ± 0.418	10.53	7.05	3.54	—	—
Difference ± 0.591	—	— 3.48	— 3.51	—	—

Oil content (by courtesy of Meggitt Limited).

Variety.	Sown 21st May.				Sown 8th June.			
	No. of seeds per gm.	Oil content %.	Iodine value (Wijs).	Acid value mg. KOH per gm.	No. of seeds per gm.	Oil content %.	Iodine value (Wijs).	Acid value mg. KOH per gm.
Punjab	152	37.05	178.7	4.9	160	36.35	177.8	2.9
Punjab 23	148	38.08	174.3	3.5	150	37.69	175.4	3.6
Walsh	123	35.93	177.1	7.1	127	34.67	180.9	3.1

9. ESTABLISHMENT OF PASTURE UNDER DIFFERENT COVER CROPS, 1941-42.

Cover crops 1941:

A. Harvested for grain and straw: Mulga Oats 18 lb. per ac., Waria wheat 33 lb. per ac., White Brunswick peas 73 lb. per ac., Prior barley 29 lb. per ac., Liral Crown flax 64 lb. per ac., Punjab linseed 30 lb. per ac., nil (ungrazed).

B. Grazed: Fulghum oats 19 lb. per ac., Waria wheat 33 lb. per ac., prairie grass 8 lb. per ac., Wimmera rye-grass $\frac{1}{2}$ lb. per ac., nil (grazed).

Superphosphate: Basal dressing of 1 cwt. per ac. per annum.

Seeded Pastures:

- (1) Dwalganup subterranean clover 2 lb. per ac., barrel medic 2 lb. per ac., *Phalaris tuberosa* 1 lb. per ac.
 (2) Lucerne 4 lb. per ac., *Phalaris tuberosa* 1 lb. per ac.

Depths of planting:

- (a) Pasture and cover crop sown at $\frac{1}{2}$ inch depth.
 (b) Pasture and cover crop sown at 1 inch: flax, linseed, prairie grass, Wimmera rye-grass; sown at $1\frac{1}{2}$ inch: oats, wheat, peas, barley.

Design: 4 replications in randomized blocks, with pasture mixtures in split plots and depths of planting in split sub-plots. Unit plots = $\frac{1}{28}$ th acre; sub-plots = $\frac{1}{56}$ th acre; split sub-plots = $\frac{1}{112}$ th acre.

Time of planting: 27th May, 1941, on fallow.

A. HARVESTED COVER CROPS.

Oats.	Wheat.	Peas.	Barley.	Flax.	Linseed.	Nil.
Yield of crop, 1941.						
(bush.)	(bush.)	(bush.)	(bush.)	(cwt.)	(bush.)	
76.45	24.38	30.76	66.32	47.18	16.44	—

Percentage occurrence of herbage species on sample areas of 1 square link, 1942.

(a) Seeded at $\frac{1}{2}$ inch depth.

Mixture (1)	%	%	%	%	%	%	%
Sub. clover	48.8	53.8	22.5	22.5	32.5	72.5	72.5
Barrel medic	3.8	1.3	1.3	1.3	2.5	18.8	2.5
<i>Phalaris</i>	1.3	7.5	28.8	5.0	10.0	37.5	66.3
Mixture (2)							
Lucerne	58.8	56.3	70.0	45.0	55.0	75.0	73.8
<i>Phalaris</i>	0.0	2.5	10.0	5.0	10.0	27.5	48.8

(b) Seeded at 1-1 $\frac{1}{2}$ inch depth.

Mixture (1)	%	%	%	%	%	%	%
Sub. clover	10.0	27.5	7.5	10.0	21.3	62.5	45.0
Barrel medic	1.3	1.3	2.5	1.3	6.3	13.8	0.0
<i>Phalaris</i>	0.0	0.0	2.5	1.3	7.5	26.3	50.0
Mixture (2)							
Lucerne	8.8	23.8	3.8	38.8	20.0	52.5	67.5
<i>Phalaris</i>	0.0	1.3	2.5	0.0	3.8	11.3	25.0

Total yields of herbage in cwt. per ac., 1942.

(a) Seeded at $\frac{1}{2}$ inch depth.

Mixture (1)	25.08	30.17	34.65	29.69	29.80	33.18	41.39
Mixture (2)	22.58	35.55	33.26	25.45	23.78	33.57	39.46

(b) Seeded at 1-1 $\frac{1}{2}$ inch depth.

Mixture (1)	25.34	27.99	32.07	29.46	25.56	31.46	41.11
Mixture (2)	21.98	24.79	35.21	23.87	36.60	29.30	34.49

B. GRAZED COVER CROPS.

Oats.	Wheat.	Prairie grass.	Wimmera rye-grass.	Nil.
Dry yield of crop in cwt. per ac., 1941.				
69.29	56.40	40.31	41.93	37.89

Percentage occurrence of herbage species on sample areas of 1 square link, 1942.

(a) Seeded at $\frac{1}{2}$ inch depth.

Mixture (1)	%	%	%	%	%
Sub. clover	48.8	50.0	26.3	30.0	42.5
Barrel medic	1.3	1.3	0.0	1.3	5.0
<i>Phalaris</i>	20.0	38.8	27.5	26.3	55.0
Mixture (2)					
Lucerne	47.5	57.5	75.0	76.3	77.5
<i>Phalaris</i>	35.0	30.0	37.5	38.8	53.8

(b) Seeded at 1-1 $\frac{1}{2}$ inch depth.

Mixture (1)	%	%	%	%	%
Sub. clover	21.3	18.8	30.0	27.5	56.3
Barrel medic	0.0	0.0	0.0	2.5	3.8
<i>Phalaris</i>	6.3	7.5	20.0	40.0	47.5
Mixture (2)					
Lucerne	0.0	18.8	56.3	71.3	67.5
<i>Phalaris</i>	6.3	5.0	23.8	28.8	43.8

Total yields of herbage in cwt. per ac., 1942.

(a) Seeded at $\frac{1}{2}$ inch depth.

Mixture (1)	32.19	30.09	31.86	30.09	37.16
Mixture (2)	27.46	27.78	29.89	29.21	32.53

(b) Seeded at 1-1 $\frac{1}{2}$ inch depth.

Mixture (1)	27.08	26.05	28.15	27.14	32.38
Mixture (2)	30.10	27.68	28.56	28.51	33.22

Botanical and statistical analysis deferred until completion of experiment in 1943.

10. INFLUENCE OF TOP-DRESSING ON THE YIELD OF NATURAL PASTURE; 1925-42, INCLUDING A COMPARISON WITH SEEDED PASTURE, 1940-42.

Investigation commenced in 1925 on unimproved natural grassland dominated by *Danthonia* spp.

Manurial treatments:

(a) Natural pasture

- | | |
|--|-----------------------|
| A. Superphosphate 185 lb. (40 lb. P ₂ O ₅) per ac. | } annually from 1925. |
| B. Superphosphate 185 lb. + nitrate of soda 78 lb. (12 $\frac{1}{2}$ lb. N.) per ac. | |
| C. Nil. | |
| D. Ground rock phosphate 103 lb. (40 lb. P ₂ O ₅) per ac. | |
| E. Basic slag 260 lb. (40 lb. P ₂ O ₅) per ac. | |

(b) Seeded pasture

- | | |
|--|-----------------------|
| F. Superphosphate 92.5 lb. (20 lb. P ₂ O ₅) per ac. | } annually from 1940. |
| G. Superphosphate 185 lb. (40 lb. P ₂ O ₅) per ac. | |
| H. Superphosphate 185 lb. (40 lb. P ₂ O ₅) per ac. | |

Design: Single replication of each treatment.

Area of plot: $1\frac{3}{15}$ th acre subdivided into 5 equal areas. Ten quadrat areas each of 2 $\frac{1}{2}$ square metres are protected from grazing and are cut for determination of yield at end of season.

Each section of the whole plot is grazed in rotation by a flock of Merino wethers assigned to it; their grazing is restricted to the particular plot or pasture similarly treated.

The pasture of plot F consists mainly of annual species while plots G and H consist of a seeded pasture, of which *Phalaris tuberosa* is the main species. Hay is cut from one section of plot H in each year and fed back to the sheep during the winter.

Mean yields of air-dry herbage in cwt. per ac.

		Treatment.							
		A	B	C	D	E	F	G	H
Mean	1940	26.48	30.30	29.48	33.86	28.41	42.30	49.10	51.00
	(1925-40)	45.46	50.91	32.59	43.53	48.52	*	*	*
	1941	37.05	42.83	35.63	46.32	43.77	54.65	59.30	60.57
	1942	49.86	63.88	41.14	60.19	59.44	64.12	73.61	75.45
Mean	{ A-E (1925-42)	45.24	51.18	33.23	44.61	48.87	*	*	*
	{ A-H (1940-42)	37.80	45.67	35.42	46.79	43.87	53.69	60.67	62.34

Mean yield of legumes, cwt. air-dry herbage per ac.

		Treatment.							
		A	B	C	D	E	F	G	H
Mean	1940	5.48	4.43	3.16	1.83	3.37	4.78	13.94	15.67
	A-E (1925-40)	12.85	8.90	5.75	8.90	10.40	*	*	*
	1941	9.73	3.62	2.54	1.45	2.06	Nil	12.75	15.07
	1942	2.35	3.09	3.07	1.32	2.74	1.46	1.48	1.87
Mean	{ A-E (1925-42)	12.09	8.28	5.42	8.07	9.51	*	*	*
	{ A-H (1940-42)	5.85	3.71	2.92	1.53	2.72	2.08	9.39	10.87

* First year of inclusion 1940.

11. CARRYING CAPACITY, WOOL PRODUCTION AND LIVE-WEIGHT INCREASES OF SHEEP ON NATURAL AND SEEDED PASTURES, 1940-42.

Treatments: A-H as in Table 10.

Stock carrying capacity. Sheep days grazing per ac.

		Treatment.								
		A	B	C	D	E	F	G	H	Mean (A-E)
Mean	1940	1,181	1,129	1,006	1,190	1,085	1,680	1,750	1,811	1,118
	A-E (1928-40)	1,591	1,792	1,051	1,516	1,720	*	*	*	1,534
	1941	1,035	1,119	913	1,075	1,118	1,415	1,367	1,530	1,052
	1942	1,566	1,738	1,254	1,597	1,545	1,565	1,629	1,542	1,540
Mean	{ A-E (1928-42)	1,552	1,744	1,055	1,492	1,668	*	*	*	1,502
	{ A-H (1940-42)	1,261	1,329	1,058	1,287	1,249	1,553	1,582	1,628	1,368 (A-H)

* First year of inclusion 1940.

Mean weight of wool per sheep in lb.

		A	B	C	D	E	F	G	H
Mean	1940	11.69	13.05	12.39	12.33	12.74	12.37	12.48	12.30
	1941	10.85	12.41	11.62	11.38	11.55	11.05	11.20	10.85
	1942	11.60	12.24	13.08	12.92	12.19	12.50	12.68	12.37
	(1940-42)	11.38	12.57	12.36	12.21	12.16	11.97	12.12	11.84

Mean live weights of sheep in lb.

		Live weight increase for period.		Live weight increase for period.		Live weight increase for period.		Total live weight increase.
		27.6.40.	24.12.40.	29.12.41.	16.12.42.	27.6.40.	24.12.40.	29.12.41.
A	82.5	91.1	8.6	111.1	20.0	115.3	4.2	32.8
B	84.7	100.5	15.8	118.8	18.3	123.0	4.2	38.3
C	82.9	104.3	21.4	115.1	10.8	127.0	11.9	44.1
D	82.2	102.3	20.1	113.4	16.1	123.7	5.3	41.5
E	83.1	98.3	15.2	119.1	20.8	121.1	2.0	38.0
F	83.8	93.9	10.1	122.2	28.3	130.8	8.6	47.0
G	84.7	84.0	— 0.7	114.7	30.7	127.9	13.2	43.2
H	82.7	79.8	— 2.9	111.1	31.3	125.9	14.8	43.2

12. EFFECT OF SUPERPHOSPHATE AND SURFACE CULTIVATION ON THE YIELD OF A SEEDED PASTURE.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass, Dwalganup subterranean clover.
Sown 15th May, 1936.

Superphosphate: Dressing applied per ac. per annum, $P_0 = \text{Nil}$, $P_1 = 1$ cwt., $P_2 = 2$ cwt., $P_3 = 3$ cwt.

Cultivation: $C_0 = \text{Nil}$, $C_1 = \text{surface cultivated each autumn}$.

Design: Phosphate treatments arranged in a 4×4 Latin square.

Area of main plot: $\frac{1}{12.5}$ th acre. Half of each plot surface cultivated. Plots sampled for yield and grazed 4 times annually at 6-weekly intervals.

Yield of oven-dry herbage in cwt. per ac.

1941	P_0	P_1	P_2	P_3	Mean ± 0.97
C_0	41.62	47.62	43.96	45.77	44.74
C_1	40.43	44.60	45.95	45.30	44.07
Mean ± 1.70	41.02	46.11	44.95	45.53	44.40
1942					Mean ± 0.87
C_0	45.32	51.60	52.30	50.72	49.99
C_1	44.81	50.47	54.12	48.90	49.57
Mean ± 0.93	45.06	51.04	53.21	49.81	49.78
Mean 1937-42					Mean ± 0.68
C_0	34.70	43.10	42.20	42.27	40.57
C_1	35.63	39.82	43.08	43.75	40.57
Mean ± 0.95	35.17	41.46	42.64	43.01	40.57

13. EFFECT OF DIFFERENTIAL GRAZING MANAGEMENT ON THE YIELD AND BOTANICAL COMPOSITION OF A SEEDED PASTURE.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass and Dwalganup subterranean clover.
Sown 15th May, 1936.

Fertilizer treatment: Superphosphate 2 cwt. per ac. per annum 1937-41; 1 cwt. per ac. in 1942.

Intensities of grazing: 2, 4, and 6 sheep per ac. per annum.

Grazing cycles: 3, 6, and 9 weeks.

Mowing treatment: Hay and no hay.

Treatments: All combinations of intensity of grazing, grazing cycle, and hay treatment.

Design: 18 treatments in 3 randomized blocks.

Area of plot: $\frac{1}{4}$ th acre. Each plot separately fenced. Each plot individually grazed by Merino wethers for 6 days in each cycle.

Grazing treatments discontinued at end of final grazing cycle in 1941.

Mean yields of oven-dry herbage in cwt. per ac. at 9th September, 1941.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks).						Mean.	
	3		6		9		No hay.	Hay.
	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.
2	20.7	31.9	21.4	32.2	27.4	33.2	23.2	32.4
4	27.7	25.4	30.9	40.2	34.1	33.1	30.9	32.9
6	25.6	28.3	28.1	31.8	33.9	38.2	29.2	32.8
Mean	24.7	28.5	26.8	34.7	31.8	34.8	27.8	32.7

Mean yield of oven-dry herbage in cwt. per ac., 1942.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks).							
	3		6		9		Mean.	
	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.
2	36.8	37.3	34.7	38.5	36.9	37.3	36.1	37.7
4	45.9	40.6	38.3	39.2	40.5	33.9	41.6	37.9
6	45.5	39.4	45.2	42.2	40.9	37.8	43.9	39.8
Mean	42.7	39.1	39.4	40.0	39.4	36.3	40.5	38.5

Mean hay yields in cwt. per ac. 1939-41.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks).			Mean.
	3	6	9	
2	36.3	35.9	37.4	36.5
4	36.4	29.3	24.8	30.2
6	27.6	28.2	25.0	26.9
Mean	33.4	31.1	29.1	31.2

Mean weight of rhizomes and roots (to three inches) of Phalaris tuberosa, April, 1942, cwt. per ac. of oven-dry material.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks).							
	3		6		9		Mean.	
	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.	No hay.	Hay.
2	45.5	24.4	49.5	35.7	69.0	37.4	54.7	32.5
6	23.0	19.2	34.7	31.2	42.5	44.7	33.4	31.7
Mean	34.2	21.8	42.1	33.5	55.8	41.0	44.0	32.1

Estimated carrying capacity of sheep per ac. in each season.

Sheep per acre	Grazing cycle (weeks).									
	3			6			9			
Year.	2	4	6	2	4	6	2	4	6	Mean.
1937	6.7	8.0	7.0	6.1	6.3	7.4	7.1	5.2	7.0	6.8
1938	7.0	8.7	8.6	7.5	7.5	9.4	7.9	6.6	8.5	8.0
1939	8.6	9.7	9.2	8.2	8.6	9.0	8.1	7.9	8.3	8.6
1940	3.6	4.3	6.0	3.8	4.6	6.0	3.8	4.0	6.0	4.7
1941	8.2	9.5	9.6	8.2	7.9	9.0	8.1	7.8	9.4	8.7
Mean	6.8	8.0	8.1	6.8	7.0	8.2	7.0	6.3	7.8	7.3

Percentage botanical composition, 1937-42 (all plots).

Year	Two sheep per ac.											
	1937.		1938.		1939.		1940.		1941.		1942.	
Grazing cycle (weeks)	3	9	3	9	3	9	3	9	3	9	3	9
Wimmera rye-grass	10.4	13.2	1.1	1.3	0.8	1.2	0.5	1.3	—	—	0.1	0.1
Phalaris	66.1	52.0	60.3	62.9	55.0	68.6	66.9	61.7	69.7	71.8	57.6	63.5
Sub. clover	23.0	31.8	36.9	32.0	37.8	25.0	29.4	31.8	25.3	23.4	14.9	20.5
Miscellaneous	0.5	3.0	1.7	3.8	6.4	5.2	3.2	5.2	5.0	4.8	27.4	15.9

Six sheep per ac.

Year	Six sheep per ac.											
	1937.		1938.		1939.		1940.		1941.		1942.	
Grazing cycle (weeks)	3	9	3	9	3	9	3	9	3	9	3	9
Wimmera rye-grass	14.3	15.1	1.4	3.4	—	1.6	0.1	2.3	—	0.1	0.1	0.1
Phalaris	27.7	49.5	43.8	56.3	28.2	49.5	38.5	54.8	35.4	67.9	33.2	50.6
Sub. clover	56.9	31.4	45.9	32.7	40.1	24.5	38.8	36.8	33.0	18.7	3.6	9.1
Miscellaneous	1.1	4.0	8.9	7.6	31.7	24.4	22.6	6.1	31.6	13.3	63.1	40.2

14. YIELD TRIALS OF NEW CROSSBRED WHEATS, 1941.

A. EARLY SOWN FIELD PLOTS AT WAITE INSTITUTE.

Date of sowing: 7th June.

Seed rate: 80 lb. per ac.

Superphosphate: 1 cwt. per ac.

Area of plot: $\frac{1}{52}$ nd acre.

Rainfall (seeding to harvest): 16.9 inches.

Design: Randomized blocks of 4 replications.

	Strain No.	Mean yield bush. per ac.	Bushel weight.
1. (Gluyas x Hope) x Nabawa	(39-248)	58.8	61.3
2. Nabawa x (Riverina x Hope)	(38-356)	58.7	63.8
3. (Gluyas x Hope) x Nabawa	(39-236)	51.9	62.8
4. Nabawa x (Nabawa x Hope)	(39-149)	51.8	62.5
5. Ghurka x Nabawa	(38-301)	47.9	61.0
6. Ghurka x Nabawa	(39-111)	46.2	60.5
7. Ghurka x Nabawa	(39-103)	42.8	62.8
8. Ghurka	(40-YP58)	41.3	56.3
9. Seewari	(33-101)	34.7	53.3
10. Rancee 4H	(40-LFP705)	26.1	54.5

Standard deviation of difference between two means = 1.8 bush. per ac.

B. LATE SOWN FIELD PLOTS AT WAITE INSTITUTE.

Date of sowing: 24th June.

Seed rate: 80 lb. per ac.

Superphosphate: 1 cwt. per ac.

Area of plot: $\frac{1}{65}$ th acre.

Rainfall (seeding to harvest): 15.7 inches.

Design: Balanced incomplete blocks of 5 replications.

	Strain No.	Mean yield bush. per ac.	Bushel weight.
1. Nabawa x Hope	(38-107)	43.1	63.0
2. Nabawa x Hope	(39-349)	42.4	64.0
3. Nabawa x Hope	(38-233)	42.4	64.5
4. Nabawa x (Riverina x Hope)	(39-129)	41.6	62.8
5. Nabawa x Hope	(38-116)	41.2	64.5
6. Nabawa x Hope	(38-109)	41.0	64.0
7. Nabawa x Hope	(38-112)	40.1	64.0
8. Nabawa x Hope	(37-76)	38.8	63.8
9. Florence x Nabawa	(38-228)	30.8	58.5
10. [(Florence x Nabawa) x Free Gallipoli] x Dundee	(39-16)	30.4	59.0
11. Florence x Nabawa	(37-72)	29.2	59.3
12. Nabawa x Hard Federation	(39-453)	28.5	55.5
13. Nabawa x Hard Federation	(37-443)	26.5	56.0
14. Gluwari	(Aq.1057)	26.1	56.5
15. Bencubbin	(40-SFP819)	24.6	56.3
16. Pusa 4 x Dundee	(39-3)	23.5	51.3
17. Waria	(36-18)	22.1	53.5
18. [(Florence x Nabawa) x Free Gallipoli] x Dundee	(39-13)	21.1	55.0
19. Nabawa x Dundee	(39-9)	19.9	53.3
20. Rancee 4H	(40-LFP705)	16.2	51.8
21. [Nabawa x (Nabawa x Hope)] x Dundee	(39-44)	14.9	46.3

Standard deviation of difference between two means = 1.9 bushels per ac.

C. FIELD PLOTS AT SADDLEWORTH.

Date of sowing: 1st July.

Seed rate: 80 lb. per ac.

Superphosphate: 140 lb. per ac.

Area of plot: $\frac{1}{18}$ th acre.

Rainfall (seeding to harvest): 14.8 inches.

Design: Randomized blocks of 4 replications.

	Strain No.	Mean yield bush. per ac.	Bushel weight.
1. Nabawa x Hope	(37-76)	43.3	58.5
2. Quadrat	F.W.C.	22.5	52.5
3. Seewari	(33-101)	19.1	49.5
4. Ghurka x Nabawa	(38-301)	16.7	51.8
5. Pindar	F.W.C.	15.5	49.0
6. Nabawa x Hard Federation	(37-443)	14.6	48.0
7. Tuela Ghurka	F.W.C.	12.9	49.8
8. Rancee 4H	(40-705)	9.9	51.0
9. Regalia	F.W.C.	9.6	47.5
10. Magnet	F.W.C.	6.4	42.8

Standard deviation of difference between two means = 0.8 bushels per ac.

D. FIELD PLOTS AT YURGO.

Date of sowing: 30th May.

Seed rate: 50 lb. per acre.

Superphosphate: 130 lb. per acre.

Area of plot: $\frac{1}{22}$ nd acre.

Design: Randomized blocks of 4 replications.

	Strain No.	Mean yield bush. per ac.	Bushel weight.
1. Nabawa x Hope	(37-76)	8.5	58.5
2. Ghurka	(40-SFP1027)	8.1	53.8
3. Nabawa x Hard Federation	(37-443)	7.4	55.0
4. Florence x Nabawa	(37-72)	7.3	55.5
5. Seewari	(33-101)	7.3	53.0
6. Ghurka x Nabawa	(38-301)	7.0	54.0
7. Bencubbin	(40-SFP819)	6.4	54.3
8. Gluwari	(Aq1057)	6.2	52.8
9. [(Florence x Nabawa) x Free Gallipoli] x Dundee	(39-13)	6.1	52.0
10. Rancee 4H	(40-LFP705)	4.9	54.5

"z" test not significant.

15. YIELD TRIALS OF NEW CROSSBRED WHEATS, 1942.

A. EARLY SOWN FIELD PLOTS AT WAITE INSTITUTE.

Date of sowing: 8th June.

Seed rate: 72 lb. per ac.

Superphosphate: $\frac{1}{2}$ cwt. per ac.Area of plot: $\frac{1}{72}$ nd acre.

Rainfall (seeding to harvest): 20.9 inches.

Design: Randomized blocks of 4 replications.

	Strain No.	Mean yield. bush. per ac.
1. (Gluyas x Hope) x Nabawa	(39-248)	49.0
2. Ghurka	(41-LFP501)	47.6
3. Sewari	(33-101)	47.3
4. Ghurka x Nabawa	(39-111)	46.7
5. Rancee 4H	(Aq1565)	46.4
6. (Gluyas x Hope) x Nabawa	(39-236)	46.4
7. Ghurka x Nabawa	(39-103)	45.8
8. Nabawa x (Sepoy x Hope)	(40-303)	45.4
9. Nabawa x (Riverina x Hope)	(38-356)	44.6
10. Ghurka x (Pusa 4 x Ford)	(40-42)	43.4

"z" test not significant.

B. FIELD PLOTS AT SADDLEWORTH.

Date of sowing: 5th August.

Seed rate: 94 lb. per ac. (marked *)
84 lb. per ac. for remainder.

Superphosphate: 140 lb. per ac.

Area of plots: Block 1, $\frac{1}{18}$ th acre.Block 2, $\frac{1}{19}$ th acre.

Rainfall (seeding to harvest): 10.0 inches.

Design: Randomized blocks of 4 replications.

Block 1.	Strain No.	Mean yield. bush. per ac.
1. *Nabawa x (Riverina x Hope)	(38-356)	49.3
2. *Warigo	(37-76)	47.6
3. *Bobin x Gaza x Bobin	(41-SFP1064)	46.7
4. *Eureka II	(41-FVT)	46.6
5. *(Gluyas x Hope) x Nabawa	(39-248)	42.7
6. Tuela Ghurka	(F.W.C.)	42.3
7. [(Florence x Nabawa) x Free Gallipoli] x Dundee	(39-16)	40.8
8. *Ranee 4H	(Aq1565)	38.3

Standard deviation of difference between two means = 1.5 bushels per ac.

* Plump seed sown at 94 lb. per ac.

Block 2.	Strain No.	Mean yield bush. per ac.
1. Seewari	(33-101)	46.6
2. Werribee Ghurka	(41-LFP501)	45.2
3. Nabawa x Hard Federation	(37-443)	44.6
4. Pindar	(F.W.C.)	43.9
5. Quadrat	(F.W.C.)	41.7
6. Ghurka x Nabawa	(39-111)	41.7
7. Tuela Ghurka	(F.W.C.)	41.3
8. Magnet	(F.W.C.)	29.4

Standard deviation of difference between two means = 0.9 bushels per ac.

